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Operation and Maintenance Considerations for Land Treatment Systems

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West Chester, PA

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The objective of this study was to focus on strategies and problems associated with the operation and maintenance of the three major types of land application systems, i.e., slow rate, rapid infiltration, and overland flow.

In addition, the effect of various methods and levels of pretreatment prior to land application were studied. 28 land application sites throughout the United States were visited. During the site visits, the information obtained was divided into two general categories: O&M practices currently in use at the facilities, and O&M-related factors which hinder operation of the facilities. The O&M practices currently in use at the facilities were further divided into staffing process control and operation, and O&M costs.

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OPERATION AND MAINTENANCE CONSIDERATIONS
FOR
LAND TREATMENT SYSTEMS

by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communication link between the researcher and the user community.

The purpose of this project was to evaluate the operation and maintenance considerations at operating land treatment facilities throughout the United States. Since the U.S. Environmental Protection Agency has been encouraging the use of alternative technologies the Plant Operation and Design Program funded this project to determine if there were any chronic O&M problems or design deficiencies limiting the performance at operational facilities. This project also documented the O&M costs of land treatment systems to determine if there were significant differences between actual costs and those reported in the literature.

Francis T. Mayo
Director
Municipal Environmental Research
 Laboratory

ABSTRACT

Recently conducted research on land treatment has focused on the areas of process development and the long-term environmental effects of land application of wastewater. The previous research, however, did not focus on the issue of operation and maintenance of the land treatment facilities following design, construction, and initial start-up. The objective of this study was to focus on strategies and problems associated with the operation and maintenance of item facilities.

The study focused on the three major types of land application systems, i.e., slow rate, rapid infiltration, and overland flow. In addition, the effect of various methods and levels of pretreatment prior to land application were studied. Therefore, the impact of both prior treatment and the type of land treatment system in use was assessed in terms of operation and maintenance of the various facilities.

Toward this goal, 28 land application sites throughout the United States were visited. During the site visits, the information obtained was divided into two general categories: O&M practices currently in use at the facilities, and O&M-related factors which hinder operation of the facilities. The O&M practices currently in use at the facilities were further divided into staffing, process control and operation, and O&M costs.

The second category of information collected during the site visits was related to factors that hinder operation and maintenance of the land treatment sites. This category included design deficiencies, mechanical reliability, plant layout, climate, and operator limitations. Where applicable, groundwater monitoring was reviewed, and in addition, the adequacy of buffer zones was assessed through interviews with site neighbors.

Following the 28 site visits (which consisted of 18 slow rate, seven rapid infiltration, and four overland flow land treatment facilities) and the data analysis portion of the study, the following conclusions have been drawn. For the sites visited, the slow rate system staffing requirements and O&M costs are lower than reported in the literature, whereas rapid infiltration and overland flow system costs and staffing requirements are in agreement with the literature data. Additionally, both slow rate and rapid infiltration systems are adequately operated, and insufficient data exist to assess overland flow operations.

This report was submitted in fulfillment of Contract No. 68-02-2775 by Roy F. Weston, Inc., under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period 2 January 1979 to 31 December 1980, and the work was completed as of 31 December 1980.

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The following individuals provided significant input to this project:

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SECTION 1

INTRODUCTION

Land treatment of municipal wastewater has been practiced since 1840. The use of land to treat domestic wastewater has received major impetus recently with the passage of the 1972 Amendments (PL 92-500) and the 1977 Amendments (PL 95-217) to the Federal Water Pollution Control Act. The 1977 Amendments, the Clean Water Act, provide certain incentives for funding land treatment systems through the U.S. Environmental Protection Agency (EPA) Construction Grants Program. These incentives involve the provisions of the Act which encourage the use of innovative and alternative technology for the treatment of municipal wastewater. The innovative and alternative technology program places major emphasis on the planning, design, and construction of cost-effective municipal treatment works that maximize recycling and reclamation of water, nutrients, and energy, while minimizing adverse environmental and public health impacts. Because of these developments, land treatment of wastewater has become a viable alternative.

Previous EPA research has focused on two aspects of the land treatment of wastewater: the long-term environmental effects of land treatment, and the design considerations for land treatment systems. On the question of the long-term effects of land treatment on soils, crops, groundwater, and other environmental components, EPA has recently produced a series of 10 documents which present the effects of long-term wastewater application at selected slow-rate and rapid infiltration sites. These studies are intended to provide new insights into the long-term effects of land treatment of municipal wastewater. In the area of land treatment system design, EPA (in cooperation with the U.S. Army Corps of Engineers and the U.S. Department of Agriculture) produced the Process Design Manual for Land Treatment of Municipal Wastewater (EPA, 1977). This manual, which is currently undergoing revision, is the major data source for the design of land treatment systems. Results reported in this publication related to design will be incorporated into the revised manual when it is reissued.

None of these documents adequately addresses the issues of operation and maintenance of land treatment systems. The purpose of the study described in this report was to provide information on operation and maintenance, staffing, and costs. Also, the study was intended to describe problems currently being experienced at land treatment sites due to operator and/or design limitations. The study was broken into two phases.

In the first phase, a project team visited various sites using land treatment systems to collect information on practices currently in use. The information was collected on several general areas.

One area was facility staffing. The data collected included numbers and functions of the people engaged in operating and maintaining the land treatment system and other treatment systems at the site. This information was collected so that recommendations on staff size and qualifications could be tabulated and proposed.

Another type of data collected during the site visits was in the area of process control and operational information. Information collected included the operational strategy used by the operator to decide where, when, and how much wastewater should be applied. In addition, the preapplication treatment was reviewed in terms of its impact on the land treatment system.

A third area in which data were gathered during the site visits was operation and maintenance costs. Data on operation and maintenance costs of the land treatment system were collected, and if possible, divided into salaries, energy, chemicals, materials, and other well-defined categories. Costs due to amortization of capital equipment were not included.

During the site visits, data were also collected on factors that hinder the operation and maintenance of a land treatment facility. This included factors such as design deficiencies, mechanical reliability problems, plant layout, weather, operator limitations, and other factors causing less than optimum operation and maintenance at the facility.

The adequacy of the groundwater monitoring practices was also assessed during the site visits. Neighbors whose property was adjacent to or in the vicinity of the land treatment system were interviewed to determine the impact of the land treatment system on private individuals.

The second phase of the study was the development of definitive recommendations for procedures to improve the operation and maintenance of land treatment systems.

The recommendations were developed from two different viewpoints. The first viewpoint involved the type of land treatment system. Therefore, all three major types of land treatment systems were visited: slow-rate (irrigation), rapid infiltration (infiltration-percolation), and overland flow systems. The second viewpoint involved the degree of preapplication treatment associated with the facility. Therefore, facilities where primary-, secondary-, and tertiary-treated wastewater is applied were visited. In addition, facilities with different types of treatment, e.g., trickling filter versus activated sludge secondary treatment, were visited. The potential effects of climatic conditions were also included, where possible, and one site in a northern climate was visited in order to assess the effect of winter conditions.

The overall goal of the research project was to make specific recommendations to improve and optimize the operation and maintenance of land treatment systems.

SECTION 2

CONCLUSIONS

The following conclusions have been drawn from this study:

1. Operation and Maintenance Costs

    a. Operation and maintenance costs for slow-rate systems are typically lower than reported in the literature.

    b. Operation and maintenance costs for rapid infiltration and overland flow systems are in general agreement with the literature data.

2. Staffing

    a. Staffing requirements for slow-rate systems are typically less than reported in the literature.

    b. Staffing requirements for rapid infiltration and overland flow systems are in general agreement with literature data.

3. Operations

    a. Slow-rate and rapid infiltration systems typically are adequately operated.

    b. Insufficient data are available to assess overland flow system operations.

4. Maintenance

    a. Equipment at all three types of land treatment systems is similar to wastewater treatment plant equipment and appears adequately maintained.

5. Design Deficiencies

a. Although design deficiencies exist, only at one facility did they substantially interfere with normal operations.

SECTION 3

RECOMMENDATIONS

The following recommendations were developed as a result of this study:

1. Operation and Maintenance Costs

   a. Operation and maintenance costs for slow-rate systems can be substantially reduced by operating the system in conjunction with a farmer.

2. Staffing and Operations

   a. Joint operation of the slow-rate system with a farm is recommended, where possible, to reduce staffing requirements and improve operations.

   b. Additional training is suggested for land treatment system operators, particularly for operators of overland flow systems.

3. System Design Related to Operation and Maintenance

   a. During the design of a slow-rate land treatment system, local farmers should be contacted for input.

SECTION 4

BACKGROUND INFORMATION

LAND TREATMENT OF WASTEWATER

As discussed in the Process Design Manual for Land Treatment of Municipal Wastewater (EPA, 1977), the land treatment of wastewater encompasses a wide variety of processes. The three principal processes are slow rate, rapid infiltration, and overland flow. There are, however, other processes which are less widely used and generally less adaptable to large-scale use, including wetland and subsurface land application. In this section, brief descriptions of the three principal types of land treatment are given. More general descriptions and design guidelines can be found in the Process Design Manual.

Slow-Rate Land Treatment

The term slow-rate land treatment is used to focus attention on wastewater treatment, as opposed to the irrigation of crops. The term irrigation land treatment was used previously. In the slow-rate system, vegetation is a critical component for managing both water and nutrients. Wastewater, which is applied to the soil, is treated as it flows through the soil matrix and eventually percolates to the groundwater. Surface runoff is generally prevented by containment. The distribution of wastewater can generally be divided into two types of application: surface and sprinkler. Surface application includes ridge and furrow and border strip flooding techniques. Spray irrigation includes various types of sprinklers, such as fixed systems, moving systems, permanent systems, or portable systems.

Slow-rate systems have several objectives, including:

1. Treatment of applied wastewater.

2. Economic return from use of water and nutrients to produce marketable crops.

3. Water conservation by replacing potable water with treated effluent for irrigating landscaped areas, such as golf courses.

4. Preservation and enlargement of green belts and open spaces.

The slow-rate system is very effective in removing conventional wastewater pollutants.

Rapid Infiltration Land Treatment

In rapid infiltration land treatment (previously referred to as infiltration-percolation), the applied wastewater percolates through the soil and is treated as the wastewater travels through the soil. Except for evaporative losses, the applied wastewater percolates to the groundwater. The wastewater is applied to readily-permeable soil, such as sand or loamy sand, in spreading basins by either sprinkling or, more typically, surface irrigation. Vegetation may be present, but typically is not.

The principal objective of a rapid infiltration system is wastewater treatment. The treated wastewater may be used for:

1. Groundwater recharge.

2. Recovery of renovated water by wells or underdrains with subsequent reuse or discharge.

3. Recharge of surface streams by interception of groundwater.

4. Temporary storage of renovated water in the aquifer.

In a rapid infiltration system, removal of insoluble wastewater constituents is by filtering and straining. Suspended solids, BOD, and fecal coliforms are almost completely removed. Nitrogen removal is generally poor unless specific operating procedures are established to maximize nitrification/denitrification. Phosphorus removal can range from 70 to 99 percent, depending on the physical and chemical characteristics of the soil.

Overland Flow Land Treatment

In the overland flow method of land treatment, wastewater is applied over the upper reaches of a sloped soil and allowed to flow across a vegetated surface to runoff collection ditches.

The wastewater is treated by physical, chemical, and biological means as it flows down the relatively impermeable slope in a thin film. An impermeable soil or a subsurface barrier is used to minimize percolation.

The objectives of an overland flow system are wastewater treatment, and, to a minor extent, crop production. Treatment objectives are to achieve secondary or better effluent from screened wastewater, or to achieve higher levels of wastewater treatment following conventional treatment. Treated wastewater can either be reused or discharged to surface water.

Table 1 shows the design features of the three types of land treatment systems. Table 2 presents a comparison of the site characteristics, and Table 3 presents the expected effluent quality.

REGULATION SUMMARY

In order to gain greater insight into the land treatment of wastewater, the regulations regarding land treatment of wastewater were collected from the nine state regulatory agencies in the states visited during the site survey. A brief summary of the data collected is presented in Table 4.

The data are far from complete, however, as many states approve each project on a case-by-case basis, and deviations from the data presented in the table are allowable.

TABLE 1. COMPARISON OF DESIGN FEATURES FOR LAND TREATMENT PROCESSES

Feature	Slow Rate	Rapid Infiltration	Overland Flow
Application techniques	Sprinkler or surface.[1]	Usually surface.	Sprinkler or surface.
Annual application rate, m	0.6-6.1	6.1-171	3.0-21
Field area required, ha[2]	23-227	0.81-23	6.5-45
Typical weekly application rate, m	0.013-0.102	0.102-3.0	0.0635-0.152[3] 0.152-0.406[4]
Minimum preapplication treatment provided in United States.	Primary sedimentation.[5]	Primary sedimentation.	Screening and grit removal.
Disposition of applied wastewater	Evapotranspiration and percolation.	Mainly percolation.	Surface runoff and evapotranspiration with some percolation.
Need for vegetation	Required.	Optional.	Required.

Adapted from EPA (1977).

[1] Includes ridge-and-furrow and border strip.

[2] Field area in hectares not including buffer area, roads, or ditches for 0.0438 m^3/s (1 mgd) flow.

[3] Range for application of screened wastewater.

[4] Range for application of lagoon and secondary effluent.

[5] Depends on the use of the effluent and the type of crop.

TABLE 2. COMPARISON OF SITE CHARACTERISTICS FOR LAND TREATMENT PROCESSES

Characteristics	Slow Rate	Rapid Infiltration	Overland Flow
Slope	Less than 20% on cultivated land; less than 40% on noncultivated land.	Not critical; excessive slopes require much earthwork.	Slopes of 2 to 8%.
Soil permeability	Moderately slow to moderately rapid.	Rapid (sands, loamy sands).	Slow (clays, silts, and soils with impermeable barriers).
Depth to groundwater	0.61 to 0.91 m (minimum).	3.0 m (lesser depths are acceptable where underdrainage is provided).	Not critical.
Climatic restrictions	Storage often needed for cold weather and precipitation.	None (possibly modify operation in cold weather).	Storage often needed for cold weather.

Adapted from EPA (1977).

TABLE 3. EXPECTED QUALITY OF TREATED WASTEWATER FROM LAND TREATMENT PROCESSES

Constituent (mg/L)	Slow Rate[1]		Rapid Infiltration[2]		Overland Flow[3]	
	Average	Maximum	Average	Maximum	Average	Maximum
BOD	<2	5	2	5	10	15
Suspended solids	<1	5	2	5	10	20
Ammonia nitrogen as N	<0.5	2	0.5	2	0.8	2
Total nitrogen as N	3	8	10	20	3	5
Total phosphorus as P	<0.1	0.3	1	5	4	6

Adapted from EPA (1977).

[1] Percolation of primary or secondary effluent through 1.5 m (5 ft) of soil.

[2] Percolation of primary or secondary effluent through 4.5 m (15 ft) of soil.

[3] Runoff of comminuted municipal wastewater over about 45 m (150 ft) of slope.

TABLE 4. STATE REGULATION MATRIX SUMMARY

State	Date of Regulations	Status of Regulations[1]	Is There a Required Degree of Preapplication Treatment?	Is Groundwater Monitoring Required?	Method of Minimizing Potential Health Impacts[2]
California	1978	In effect	Yes, as function of end use	No	Degree of preapplication treatment as function of end use
Massachusetts	All decisions on a case-by case basis; minimum of primary treatment prior to application.				
Michigan	January 1980	Proposed	No	Yes	None
Mississippi	May 1979	Final draft	Yes, intermediate	May be required	15-30 m buffer zone RI and OF. 30-61 m buffer zone SR. Fencing required. Chlorination on a case-by-case basis.
New Jersey	Not known	Draft guidelines	Yes, secondary	Yes	61-m buffer zone if open fields. 30-m buffer zone if dense vegetation.
New York	May 1977	Proposed	No	Yes	No actual or potential public health hazard.
Pennsylvania	1972	Guidelines	Yes, secondary	Yes	Controls on adjacent land use. Disinfection.
South Carolina	September 1975	Guidelines	No	Yes	30-m buffer zone, fencing with signs.
Texas	Not known	Design criteria	Yes, specified organic loading rates	Yes	Operation must be approved by local health authorities and Texas Department of Health Resources.
Vermont	July 1979	Regulations	Yes, slow rate, secondary. Rapid infiltration tertiary.	Yes	Required minimum isolation distance of 30 m, depending on site conditions and system type.

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[1] Regulations as of May 1980.

[2] Not including groundwater quality monitoring.

SECTION 5

PROJECT IMPLEMENTATION

Data presented by Jewell and Seabrook (1979) indicate there are approximately 2,210 land treatment facilities (excluding septic systems) in operation in the United States. Based on the 1976 Needs Survey, plans call for a significant number of additional land treatment systems in the future. Therefore, there exists a wide variety of land treatment systems which could be visited.

In the selection of facilities to be visited, the first step consisted of reviewing the output from the EPA-1 computer program, which gave the results of the 1978 Needs Survey. This indicated that approximately 720 facilities were either using land treatment, or considering the addition of a land treatment system. The data from the Needs Survey were then summarized in terms of:

1. Whether or not the facilities were existing or planned.

2. What the future of the facilities would be, i.e., whether they were to be abandoned, upgraded, or enlarged.

Plants were then characterized by flow, degree of preapplication treatment, and climatic location. It was then decided that, where possible, plants which were to be abandoned would not be visited as the operation and maintenance of these facilities would probably not reflect normal practices. In addition, it was decided that no plant smaller than 0.0022 m^3/s (50,000 gpd) or larger than 0.876 m^3/s (20 mgd) would be visited, as the majority of treatment facilities in the United States fall within this range. Because of the small number of plants using overland flow, two sites using this method with less flow were studied.

To reflect the geographic distribution of plants, it was decided to visit plants in proportion to the total percentage of plants in operation in that particular area. Multiple facilities were, therefore, visited in the states of California, Texas, and Michigan as these three states account for a large percent of the land treatment facilities in the United States. In all, 28 sites were chosen. Two facilities, namely, the U.S. Army Corps of Engineers Waterways Experimental Station overland flow research facility in Utica, Mississippi (a facility recently closed) and the Campbell's Soup, Paris, Texas overland flow treatment facility (an industrial facility) were visited as there is a small number of operational overland flow facilities in the United States.

Prior to any of the site visits, a site questionnaire and checklist was prepared so that the data could be collected in the field in a complete and orderly fashion. Following some of the earlier visits, modifications to the questionnaire were required, and these were incorporated. The final version of the trip questionnaire is presented in Appendix B.

During the site visits, data were collected in one of three ways. The first method was filling out the field trip questionnaire/checklist. The second method was recording the site investigator's comments on a tape recorder, and the third method consisted of taking photographs of each site.

After each site visit, a rough trip report was drafted. After all 28 site visits, it was discovered that there were some inaccuracies and contradictions in the data gathered. Also, some data were not available at the time of the visit. The treatment plants involved were called to resolve any data that appeared contradictory or to obtain any data that were missing. The final trip reports are presented in Appendix A.

EVALUATION OF LAND TREATMENT SYSTEMS

The evaluation of a land treatment system is different from the evaluation of typical wastewater treatment process in that there is little in the way of direct evidence as to the effectiveness of the land treatment system. Therefore, determination of the adequacy of a land treatment system must rely on circumstantial evidence.

The following data are needed to assess the adequacy of a land treatment system:

1. Design loadings as compared to typical design limitations.

2. Compliance/noncompliance with applicable state and Federal regulations/guidelines.

3. Visual observations (aesthetics, plant health, soil condition, etc.).

4. Groundwater monitoring data and hydrogeological considerations.

5. Maintenance practices.

6. Operational practices.

It is only through consideration of such parameters that the performance of a land treatment system can be adequately assessed. In other words, a direct standard, such as effluent quality, by which the system can be gauged is not available. Therefore, adherence to reliable design, operation, and maintenance practices is used to determine the presumptive adequacy of a system.

SITE LOCATIONS

The sites visited were selected based on a variety of factors, including degree and type of preapplication treatment, climatic conditions, and type of land application system. Using these guidelines, the selected sites have been plotted geographically, as shown in Figure 1. The sites are clustered around California, Michigan, and Texas since this is representative of the geographical distribution of land treatment systems in the United States. Figure 1 also presents the five different climatic zones in the United States, as presented by Sullivan, et al (1973). At least one site was visited in each of the climatic zones.

SITE DATA

For each of the sites visited, the facility name, facility location, flow rate, and type of preapplication treatment have been compiled. These data for the 28 sites visited are shown in Table 5. The same data are compiled in Tables 6, 7 and 8 for each type of land treatment system. It should be noted that facility 007, the Fontana Regional Plant No. 3, consists of both a rapid infiltration and a slow-rate system, and therefore appears on both tables. In summary, 18 slow-rate sites, seven rapid infiltration sites, and four overland flow sites were visited.

It should be noted that the term "oxidation pond" as used in this report is a general term, and includes a range of different types of treatment ponds, including high-rate aerobic, aerobic, facultative, and maturation ponds.

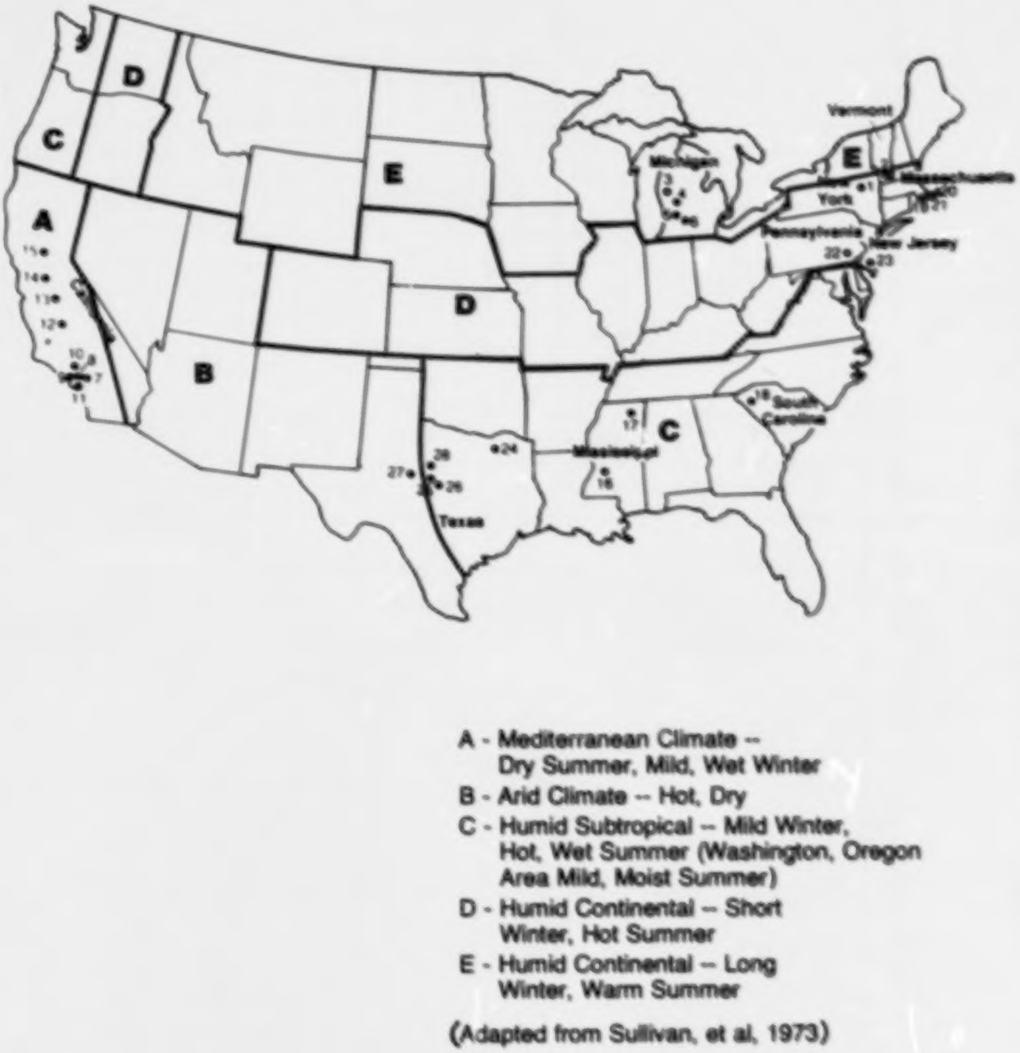
A
B
C
D
E
Vermont
Michigan
New York
Massachusetts
Pennsylvania
New Jersey
South Carolina
Mississippi
Texas
California
A - Mediterranean Climate -- Dry Summer, Mild, Wet Winter
B - Arid Climate -- Hot, Dry
C - Humid Subtropical -- Mild Winter, Hot, Wet Summer (Washington, Oregon Area Mild, Moist Summer)
D - Humid Continental -- Short Winter, Hot Summer
E - Humid Continental -- Long Winter, Warm Summer
(Adapted from Sullivan, et al, 1973)

Figure 1. Geographical and climatic locations of land treatment sites visited.

TABLE 5. PREAPPLICATION TREATMENT MATRIX

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection		Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other	Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
Village of Lake George WWTP	Lake George, NY	001	0.0280								x	x		x					x							
North Branch Fire District No. 1 WPCF	West Dover, VT	002	0.0049		x	x										x			x		x					
City of Hart WWTF	Hart, MI	003	0.0267														x	x			x[2]					
City of Fremont WWTP	Fremont, MI	004	0.0133		x[3]	x[3]												x			x					
Village of Ravenna STP	Ravenna, MI	005	0.0032															x								
City of Wayland WWTP	Wayland, MI	006	0.0110														x	x			x					
Fontana Regional Plant No. 3	Fontana, CA	007	0.1266	x						x											x[2]					
Pomona Water Reclamation Plant	Pomona, CA	008	0.3505							x			x						x		x		x	x	x[4]	
Whittier Narrows Water Reclamation Plant	El Monte, CA	009	0.7010							x			x						x		x		x		x	
Palmdale Water Reclamation Plant	Palmdale, CA	010	0.0811			x				x								x								
Irvine Ranch Water District	Irvine, CA	011	0.3505	x				x		x			x						x	x	x		x			
City of Tulare WPCF	Tulare, CA	012	0.1490	x		x		x	x					x	x		x	x	x							
City of Kerman WWTP	Kerman, CA	013	0.0228		x	x		x					x					x	x							
City of Manteca WWQCF	Manteca, CA	014	0.1008	x				x					x					x	x							

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[1] m^3/s x 22.8245 = mgd
[2] Not in use.
[3] Following oxidation ponds.
[4] Used for surface discharge only.
[5] Raw wastewater preapplication treatment.
[6] Following overland flow treatment.
[7] Five-day production flow. Yearly average flow = 0.1796 m^3/s

Key

WWTP	-	Wastewater treatment plant
WPCF	-	Water pollution control facility
WWTF	-	Wastewater treatment facility
STP	-	Sewage treatment plant
WWQCF	-	Wastewater quality control facility
WPCP	-	Water pollution control plant

TABLE 5. PREAPPLICATION TREATMENT MATRIX
(continued)

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m³/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection		Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other	Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
El Dorado Hills WWTP	El Dorado Hills, CA	015	0.0197		x		x			x				x				x	x		x					
U.S. Army COE, WES Overland Flow Site	Utica, MS	016	0.0009															x								
Falkner WWTF	Falkner, MS	017	0.0012															x			x					
Easley Combined Utilities System Overland Flow Project	Easley, SC	018	0.0044		x[5]	x[5]												x			x[6]					
Town of Wareham WPCF	Wareham, MA	019	0.0140		x	x		x					x						x		x					
Chatham WPCF	Chatham, MA	020	0.0035		x	x			x				x						x							
Town of Barnstable WPCF	Hyannis, MA	021	0.0252		x	x		x	x	x																
Kendal/Crosslands Lagoon System	Kennett Square, PA	022	0.0022		x	x											x	x		x	x					
Landis Sewage Authority	Vineland, NJ	023	0.1753	x					x	x																
Campbell Soup (Texas), Inc.	Paris, TX	024	0.2234[7]						x																	
City of Coleman WWTP	Coleman, TX	025	0.0175		x			x								x			x		x[4]					
City of Santa Anna WWTP	Santa Anna, TX	026	0.0033		x			x			x							x								
City of Winters WWTP	Winters, TX	027	0.0131								x							x								
City of Sweetwater WPCP	Sweetwater, TX	028	0.0438		x			x		x				x					x							

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[1] m³/s x 22.8245 = mgd
[2] Not in use.
[3] Following oxidation ponds.
[4] Used for surface discharge only.
[5] Raw wastewater preapplication treatment.
[6] Following overland flow treatment.
[7] Five-day production flow. Yearly average flow = 0.1796 m³/s

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility
WWTF - Wastewater treatment facility
STP - Sewage treatment plant
WWQCF - Wastewater quality control facility
WPCP - Water pollution control plant

TABLE 6. SLOW-RATE PREAPPLICATION TREATMENT MATRIX

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection		Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other	Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
North Branch Fire District No. 1 WPCF	West Dover, VT	002	0.0049		x	x										x			x		x					
City of Hart WWTF	Hart, MI	003	0.0267														x	x			x[2]					
City of Fremont WWTP	Fremont, MI	004	0.0133		x[3]	x[3]												x			x					
Village of Ravenna STP	Ravenna, MI	005	0.0032															x								
City of Wayland WWTP	Wayland, MI	006	0.0110														x	x			x					
Fontana Regional Plant No. 3	Fontana, CA	007	0.1266	x						x											x[2]					
Pomona Water Reclamation Plant	Pomona, CA	008	0.3505							x			x						x		x		x	x	x[4]	
Palmdale Water Reclamation Plant	Palmdale, CA	010	0.0811			x				x								x								
Irvine Ranch Water District	Irvine, CA	011	0.3505	x				x		x			x						x	x	x		x			

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[1] m^3/s x 22.8245 = mgd
[2] Not in use.
[3] Following oxidation ponds.
[4] Used for surface discharge only.

Key

WPCF - Water pollution control facility
WWTP - Wastewater treatment plant
STP - Sewage treatment plant
WWQCF - Wastewater quality control facility
WPCP - Water pollution control plant

TABLE 6. SLOW-RATE PREAPPLICATION TREATMENT MATRIX
(continued)

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection		Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other	Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
City of Tulare WPCF	Tulare, CA	012	0.1490	x		x		x	x					x	x		x	x	x							
City of Kerman WWTP	Kerman, CA	013	0.0228		x	x		x					x					x	x							
City of Manteca WWQCF	Manteca, CA	014	0.1008	x				x					x					x	x							
El Dorado Hills WWTP	El Dorado Hills, CA	015	0.0197		x		x			x				x				x	x		x					
Kendal/Crosslands Lagoon System	Kennett Square, PA	022	0.0022		x	x											x	x		x	x					
City of Coleman WWTP	Coleman, TX	025	0.0175		x			x								x			x		x[4]					
City of Santa Anna WWTP	Santa Anna, TX	026	0.0033		x			x			x							x								
City of Winters WWTP	Winters, TX	027	0.0131								x							x								
City of Sweetwater WPCP	Sweetwater, TX	028	0.0438		x			x		x				x					x							

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[1] m^3/s x 22.8245 = mgd
[2] Not in use.
[3] Following oxidation ponds.
[4] Used for surface discharge only.

Key

WPCF	- Water pollution control facility
WWTP	- Wastewater treatment plant
STP	- Sewage treatment plant
WWQCF	- Wastewater quality control facility
WPCP	- Water pollution control plant

TABLE 7. RAPID INFILTRATION PREAPPLICATION TREATMENT MATRIX

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection			Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other		Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
Village of Lake George WWTP	Lake George, NY	001	0.0280								x	x		x					x								
Fontana Regional Plant No. 3	Fontana, CA	007	0.1266	x						x												x[2]					
Whittier Narrows Water Reclamation Plant	El Monte, CA	009	0.7010							x			x						x			x		x		x	
Town of Wareham WPCF	Wareham, MA	019	0.0140		x	x		x					x						x			x					
Chatham WPCF	Chatham, MA	020	0.0035		x	x			x				x						x								
Town of Barnstable WPCF	Hyannis, MA	021	0.0252		x	x		x	x	x																	
Landis Sewage Authority	Vineland, NJ	023	0.1753	x					x	x																	

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[1] m^3/s x 22.8245 = mgd
[2] Not in use.

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility

TABLE 8. OVERLAND FLOW PREAPPLICATION TREATMENT MATRIX

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preliminary Treatment						Primary Treatment			Secondary Treatment								Disinfection			Tertiary Treatment			
				Mechanical Bar Screen	Bar Screen	Comminutor	Barminutor	Grit Removal	Other	Primary Clarifier	Imhoff Tank	Other	Activated Sludge	Trickling Filter	Activated Bio-Filter	Oxidation Ditch	Aerated Pond	Oxidation Pond	Secondary Clarifier	Other		Chlorination	Other	Filtration	Carbon Adsorption	Dechlorination	Other
U.S. Army COE, WES Overland Flow Site	Utica, MS	016	0.0009													x											
Falkner WWTF	Falkner, MS	017	0.0012													x						x					
Easley Combined Utilities System Overland Flow Project	Easley, SC	018	0.0044		x[2]	x[2]										x						x[3]					
Campbell Soup (Texas), Inc.	Paris, TX	024	0.2234[5]						x[4]																		

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[1] $m^3/s \times 22.8245 = mgd$

[2] Raw wastewater preapplication treatment.

[3] Following overland flow treatment.

[4] Screening and oil and grease separation.

[5] Five-day production flow. Yearly average flow = 0.1796 m^3/s.

Key

WWTF - Wastewater treatment facility

TYPES OF DATA COLLECTED

During the site visits, the trip questionnaire/checklist was completed for each location. The types of data collected are summarized in Table 9.

OTHER CONSIDERATIONS

The majority of information learned during the site visits is believed to be factual. Certain questions, however, required estimation on the part of the treatment plant personnel in order to supply the required information. In cases where the personnel were unable to provide the information requested, the data were estimated, if possible, by the interviewers.

Of the questions posed, three questions proved to be the most difficult to answer. The first question involved the budget information for the operation and maintenance of the facility. For the majority of the facilities visited (26 out of 28), the budget information obtained applied to the entire treatment facility as the funds spent on land application were not separated from those for preapplication treatment. This necessitated estimation to ascertain how much money was spent in each area.

The budgetary problem is further complicated by the fact that it is sometimes difficult to decide if equipment is part of the preapplication treatment or the land application treatment system. For example, a holding pond following secondary treatment may actually function as an oxidation pond, thereby appearing to be part of the preapplication treatment system. One could also consider the holding pond as nothing more than an effluent holding pond, however, and therefore, part of the land application system. A second example is the need for effluent pumping. If effluent pumping was required for a surface discharge, then the cost of effluent pumping was associated with preapplication treatment; if the surface discharge could flow by gravity, the pumping cost was assumed to be associated with the land application system.

A further complication arose regarding budgetary information. In small towns, the cost of collection system operation and maintenance is typically included in the same budget as the treatment plant. These costs were separated out in the study.

TABLE 9. SUMMARY OF DATA COLLECTED DURING SITE VISITS

- Background Information
    - Contributory population, flows, loadings
    - Final disposition of wastewater
    - Budget
    - Instrumentation, electrical consumption
    - Analytical data
- Staffing
    - Certification
    - Background data
    - Preapplication and land application staffing
- Maintenance
    - Preventative maintenance program
    - Operation and maintenance manual
- Wastewater Preapplication Treatment System
    - Physical facilities (type and number)
    - Process flow diagram
- Land Treatment System
    - Wastewater storage
    - Wastewater distribution
    - Buffer zones, site access
    - Application rates
    - Soils information
    - Groundwater monitoring
- Facility Layout
    - Preapplication treatment system
    - Land application system
- Land Application - Agricultural Viewpoint
    - Operational strategies (wastewater applications, time and amount)
    - Operational problems
    - Crop management
- Land Application - A Neighbor's Viewpoint
    - Problems
    - Changes

The second problem question, closely related to the budgetary dilemma, involved staffing requirements for the preapplication treatment and the land treatment systems. The problem involves dividing the hours which are spent daily into preapplication and land application treatment. In addition, the collection system complications also exist.

A further complication to both the budgetary and staffing information is afforded by the different operational practices at the treatment plants. For example, at one location the preapplication treatment and land application systems may be operated and maintained by the same staff, whereas at another facility, the duties at the land treatment facility may be shared by the wastewater treatment facility personnel and/or farmer. At a third facility, however, the operation and maintenance of the land application system may be performed entirely by a farmer. Therefore, only costs incurred by the municipality during the land application portion were included, and no attempt was made to calculate costs incurred by the farmer in the operation of the land application facility, as the majority of these costs would be incurred during irrigation of a normal farm.

The third problem question concerned determining the land treatment operating strategy. The problem, however, was not how the facility was operated, but rather why the facility was operated in the mode that it was. Typically, it appeared that operational practices were gained through experience, and once practices were successful, no attempt was made to change the operation of the facility. Therefore, when questioned about the operation of the facility, the operators could typically respond how something was done, but not necessarily why it was done.

SECTION 6

EVALUATION OF CURRENT OPERATION AND MAINTENANCE PRACTICES

This section is intended to summarize information that was collected during the site visits. Table 10 presents background information for each of the 28 land treatment sites visited.

Of the sites visited, facility 018 (Easley, South Carolina Utilities System Overland Flow Project) had been in operation only two years at the time of the visit, whereas facility 027 (City of Winters, Texas) had been in use for approximately 56 years. A basic requirement for this project was that no plant was to be visited that had not been in operation a reasonable amount of time to minimize start-up related operation and maintenance problems.

In analyzing the types of land use adjacent to the land treatment systems, it can be seen that the systems are located in a wide variety of land use areas. As would be expected, the slow-rate irrigation systems were located in agricultural areas. Systems such as Pomona and Irvine Ranch, however, utilize water for landscape irrigation, and therefore, the water reuse can be in any of the land use areas. At all but four of the systems visited, 100 percent of the preapplication treatment wastewater was land applied. At facility 008 (Pomona, California), 33 percent was land applied during the winter and 66 percent during the summer; 34 percent was used in a nearby paper company year-round. At facility 015 (El Dorado Hills, California), 60 percent of the wastewater is either pumped to a lumber mill for reuse or is surface discharged. At facility 016 (Utica, Mississippi), only one-third of the water which flows into the oxidation pond is utilized in conjunction with the research project. At facility 025 (Coleman, Texas), 30 percent of the preapplication effluent was discharged to surface-water with the aim of not overirrigating the land application site. At eight of the land treatment sites, drinking water in the vicinity was supplied by groundwater, and at one location, it was supplied by both groundwater and a public system. At the remaining sites, potable water was supplied by a public water system.

TABLE 10. LAND TREATMENT SYSTEMS, BACKGROUND INFORMATION

Facility Name	Site Number	Type of System	Years in Operation	Adjacent Land Use[1]	Percent of Preapplication Effluent to Land Treatment	Drinking Water Source in Vicinity	Weather Data[2]		
							Average Annual Temperature	Average Annual Precipitation	Estimated Mean Annual Class A Pan Evaporation
							°C	m	m
Village of Lake George WWTP	001	RI	41	R	100	Public	8.2	0.95	0.84
North Branch Fire District No. 1 WPCF	002	SR	5	R,C,A	100	Well	7.8	1.09	0.89
City of Hart WWTF	003	SR	6	A	100	Well	8.3	0.84	0.94
City of Fremont WWTP	004	SR	5	A	100	Well	8.9	0.84	1.02
Village of Ravenna STP	005	SR	11	R,A	100	Well	8.5	0.80	0.99
City of Wayland WWTP	006	SR	9	A	100	Well	8.8	0.82	1.02
Fontana Regional Plant No. 3	007	RI,SR	27	I,A,O	100	Public	17.6	0.32	1.75
Pomona Water Reclamation Plant	008	SR	50	R,C,I,A,O	Winter 33 Summer 66	Public	16.7	0.42	1.65
Whittier Narrows Water Reclamation Plant	009	RI	18	R,C	100	Public	16.7	0.42	1.65
Palmdale Water Reclamation Plant	010	SR	23	A	100	Public	16.4	0.20	1.78
Irvine Ranch Water District	011	SR	11	R,C,A,O	100	Public	16.6	0.31	1.52
City of Tulare WPCF	012	SR	35+	A	100	Well	17.4	0.24	2.29
City of Kerman WWTP	013	SR	4	A,I	100	Well	16.8	0.26	2.29
City of Manteca WWQCF	014	SR	17	A	100	Well	15.9	0.30	2.03
El Dorado Hills WWTP	015	SR	5	A,O	40	Public	13.1	1.01	1.65
U.S. Army COE, WES Overland Flow Site	016	OF	4	A	33	Public	18.8	1.31	1.52
Falkner WWTF	017	OF	3	A,R	100	Public	15.9	1.38	1.40
Easley Combined Utilities System Overland Flow Project	018	OF	2	A,R	100	Public	15.4	1.32	1.30
Town of Wareham WPCF	019	RI	8	R	100	Public	11.1	1.01	0.86
Chatham WPCF	020	RI	9	R	100	Well & Public	9.7	1.10	0.81
Town of Barnstable WPCF	021	RI	45	C,R	100	Public	11.1	1.01	0.86
Kendal/Crosslands Lagoon System	022	SR	7	R	100	Public	11.9	1.10	1.19
Landis Sewage Authority	023	RI	30	I	100	Public	12.2	1.02	1.14
Campbell Soup (Texas), Inc.	024	OF	16	C,I,A	100	Public	17.3	1.15	1.91
City of Coleman WWTP	025	SR	50	A	70	Public	18.6	0.68	2.41
City of Santa Anna WWTP	026	SR	14	A	100	Public	18.6	0.68	2.41
City of Winters WWTP	027	SR	56	A	100	Public	18.2	0.55	2.49
City of Sweetwater WPCP	028	SR	22	A	100	Public	17.4	0.56	2.54

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[1] R = Residential
C = Commercial
I = Industrial
A = Agricultural
O = Other

[2] From nearest weather station.

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility
WWTF - Wastewater treatment facility
STP - Sewage treatment plant
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WPCP - Water pollution control plant

Of the 28 sites visited, facility 002 (North Branch Fire District No. 1, Dover, Vermont) was located in the coldest area, with a mean annual temperature of 7.8°C (46.0°F). The Utica, Mississippi overland flow site was located in the warmest area, with a yearly average temperature of 18.8°C (65.8°F). Precipitation ranged from a high of 1.38 m/yr (4.53 ft/yr) at the Falkner, Mississippi facility to a low of 0.20 m/yr (0.66 ft/yr) at the Palmdale, California Water Reclamation Plant. Yearly annual estimated Class A pan evaporation ranged from a high of 2.54 m (8.3 ft) in Sweetwater, Texas, to a low of 0.81 m (2.7 ft) in Chatham, Massachusetts.

The physical facilities present at the land treatment sites are presented in Table 11. From this table it can be seen that seven of the 28 land treatment systems were controlled by some sort of instrumentation system. Wastewater storage at the facilities ranged from 0 to a high of 472 days at facility 004 (City of Fremont, Michigan). Storage included any potential storage due to a variable level in an oxidation pond, plus storage in holding basins. Of interest, is the fact that none of the seven rapid infiltration systems visited had on-site storage. The overland flow site at facility 024 (Campbell Soup, Paris, Texas) had no storage, whereas the other overland flow sites had storage based on a variable level in the preapplication treatment oxidation ponds.

There were only two slow-rate systems which had no provisions for wastewater storage; these were facilities 008 and 025 (Pomona, California Water Reclamation Plant, and the Coleman, Texas Wastewater Treatment Plant). In both of these plants, however, provisions existed for surface discharge.

The land area receiving wastewater varied from a low of 0.38 ha (0.94 acres) at the Chatham, Massachusetts facility, to a high of 809 ha (2,000 acres) associated with the Irvine Ranch Water District, California. The land area usage has been plotted as a function of flow rate in Figure 2. As would be expected for the three different types of systems, three distinct areas on the graph are prevalent. The lowest land requirement is for the rapid infiltration systems. The highest land requirement is for the slow-rate systems. In the middle area are the four overland flow plants. Facility 024 (Campbell Soup, Paris, Texas) appears slightly higher on the curve than some of the other overland flow systems. This can be accounted for by a recent expansion, and the fact that the facilities receive industrial wastewater with a high organic loading. Also plotted on Figure 2 are the application land area requirements for moderately-favorable conditions, as taken from "Water Reuse and Recycling," Volume 2, OWRT/RU-79-2, U.S. Department of Interior,

TABLE 11. LAND TREATMENT SYSTEMS, PHYSICAL FACILITIES

Facility Name	Site No.	Type of System	Instrumentation System	Wastewater Storage[1] days	Land Area Used[2] ha	Soil Type	Slope of Land[3]	Number of Groundwater Monitoring Wells	Wastewater Distribution System	Wastewater Application System
Village of Lake George WWTP	001	RI	No	0	2.2	Sand	Flat	24	G,P	Infiltration beds
North Branch Fire District No. 1 WPCF	002	SR	Yes	162	13.8	Silt, sand, loam	Steep	6	P	Fixed nozzles
City of Hart WWTF	003	SR	No	102	34.8	Sand, loam	Moderate	6	P	Gated pipe, ridge and furrow
City of Fremont WWTP	004	SR	No	472	24.1	Sand, loam	Flat	32	G,P	Border strip
Village of Ravenna STP	005	SR	No	297	8.1	Sand, clay	Flat	0	G	Border strip
City of Wayland WWTP	006	SR	No	258	31.6	Sand, loam, clay	Moderate	5	P	Center pivot, big gun spray
Fontana Regional Plant No. 3	007	RI,SR	No	0	20.3	Sand, loam	Flat	0	G,P	Infiltration beds, ridge & furrow
Pomona Water Reclamation Plant	008	SR	Yes	0[4]	29.1	Widely varying	Flat-steep	0	G,P	Spray, ridge and furrow
Whittier Narrows Water Reclamation Plant	009	RI	No	0	405+	Sand	Flat	16+	G	Infiltration beds
Palmdale Water Reclamation Plant	010	SR	No	42	279	Silt, sand, loam	Flat	4	P	Side-wheel roll spray
Irvine Ranch Water District	011	SR	Yes	98	607-809 (Seasonal)	Silt, sand, clay, loam	Flat-moderate	0	P	Spray, ridge and furrow, drip
City of Tulare WPCF	012	SR	No	28	205	Sand, loam	Flat	0	G	Border strip, ridge and furrow
City of Kerman WWTP	013	SR	No	3	87.8	Sand, loam	Flat	0	G,P	Ridge and furrow
City of Manteca WWQCF	014	SR	No	4	106	Sand, loam	Flat	9	G,P	Border strip
El Dorado Hills WWTP	015	SR	No	7	8.1	Silt, loam	Moderate	0	P	Spray
U.S. Army COE, WES Overland Flow Site	016	OF	Yes	N/A	0.50	Silt, loam	Flat-moderate	0	P	Trough distribution
Falkner WWTP	017	OF	No	118	1.06	Silt, loam, clay	Flat-moderate	0	P	Spray
Easley Combined Utilities System Overland Flow Project	018	OF	Yes	44	1.9	Loam, clay, sand	Moderate	5	P	Fixed nozzle, trough, open pipe
Town of Wareham WPCF	019	RI	No	0	1.6	Sand	Flat	0	G	Infiltration beds
Chatham WPCF	020	RI	No	0	0.38	Sand, loam	Flat	0	G	Infiltration beds
Town of Barnstable WPCF	021	RI	No	0	3.2	Sand, loam[5]	Flat	0	G	Infiltration beds
Kendal/Crosslands Lagoon System	022	SR	Yes	51	3.2	Silt, loam	Moderate	11	P	Spray
Landis Sewage Authority	023	RI	No	0	26.3	Sand	Flat	3	G,P	Infiltration beds
Campbell Soup (Texas), Inc.	024	OF	Yes	0	235	Clay	Moderate	0	P	Spray
City of Coleman WWTP	025	SR	No	0	23.1	Clay, loam, silt	Flat	0	G	Border strip
City of Santa Anna WWTP	026	SR	No	369	10.9	Clay, loam, silt	Flat	0	P	Side-wheel roll spray
City of Winters WWTP	027	SR	No	9	10.5	Silt, sand, clay, loam	Flat	0	G,P	Border strip
City of Sweetwater WPCP	028	SR	No	15	115	Silt, loam, clay	Flat	0	G,P	Border strip

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[1] Includes potential storage, such as variable levels in oxidation ponds using 0.61 m (2.0 ft) minimum water depth regardless of whether or not system is operated this way. Based on current flow rate, not including precipitation or evaporation effects.

[2] Includes only land area in use, not land available for use.

[3] Flat 0-3%; moderate 3-8%; steep over 8%.

[4] An 11,356-m^3 storage basin is currently under construction.

[5] Imported sand has been used for replacement.

Key

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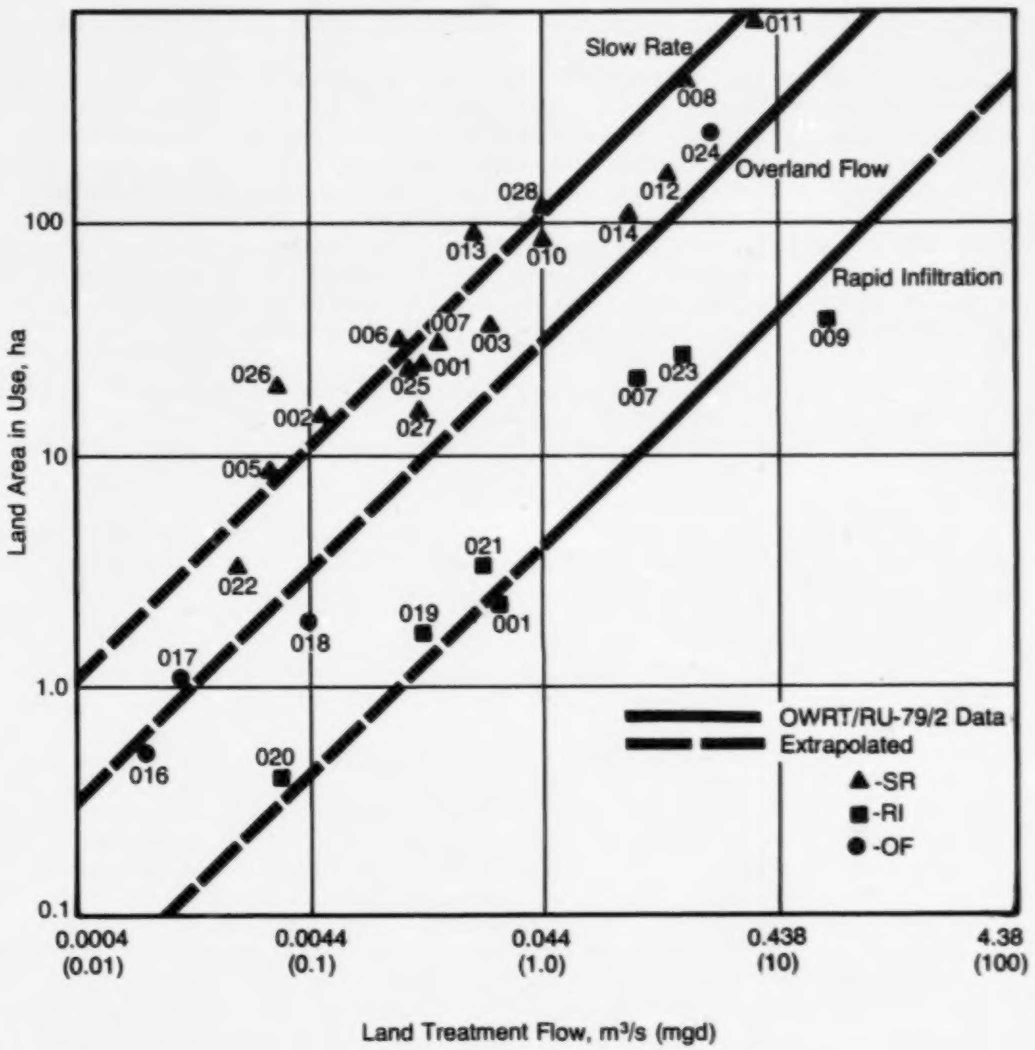

Figure 2. Land area used as a function of flow rate.

1979. Since the smallest flow contained in this report is 0.044 m^3/s (1.0 mgd), the plots are extrapolated for lower values. The field data compare favorably with the OWRT data.

Table 11 also shows the various soil types at the land treatment sites. These data were gathered from Soil Conservation Service Soil Survey Maps (where maps existed), and it can be seen that land treatment systems are adaptable to a variety of soil types. As would be expected, the rapid infiltration systems are in sand or a sand and loam soil. In addition, wastewater is applied on slopes of varying degree, from flat to steep surfaces, with wastewater being applied to a slope of over 25 percent at facility 002 (North Branch Fire District No. 1, Dover, Vermont), a woodland spray irrigation site.

At 11 of the 28 sites visited, groundwater monitoring wells were installed and routinely monitored. A further description of groundwater monitoring will be presented in a subsequent section on BPWTT monitoring.

A wide variety of wastewater distribution equipment and application system types were seen during the survey. In addition, at nine of the 28 sites, wastewater was distributed by both gravity and pumping. At three of these sites, i.e., facilities 001, 007, and 023, the older portions of the system received gravity flow, while pumping was required for the newer portions.

In Table 12, a substantial amount of the data collected during the study is presented, and will be discussed briefly in this report. A variety of contractual agreements exist, and typically these agreements are for the slow-rate system, with the exception of facility 009 (Whittier Narrows Water Reclamation Plant, California) where wastewater is purchased for groundwater recharge. In the remaining facilities, the agreements typically are for the purchase of wastewater or for rental of a portion of the city-owned land, with the stipulation that the wastewater will be utilized. At facility 012 (Tulare, California), the stipulation is that the city will receive 25 percent of the crop-generated revenues.

The electrical consumption (not including electrical usage by the end user) in terms of kwh per month is also shown in Table 12.

During the site visits, the operational staffs were questioned on the type of regulatory permit under which the facility was operated. At seven of the sites, the facilities were operating under an operating permit only. At eight sites, the facility was operating under a pretreatment quality permit, and at

TABLE 12. LAND TREATMENT SYSTEMS INFORMATION

Facility Name	Site No.	Type of System	Revenues Generated	Average Electrical Usage[1] kwh/mo	Type of Regulatory Permit[2]	O&M Manual Which Addresses Land Application On Hand?	System Operated as Designed?	Buffer Zone Size m	Public Access Controls
Village of Lake George WWTP	001	RI	0	1,365	PTQ	No	Yes	76	Woods
North Branch Fire District No. 1 WPCF	002	SR	0	4,700	OP	Yes	Yes	61	Fence and signs
City of Hart WWTF	003	SR	0	16,228	GWQ	Yes	Yes	15	Fence and signs
City of Fremont WWTP	004	SR	0	3,505	GWQ	Yes	Yes	15	Fence and signs
Village of Ravenna STP	005	SR	0	0	SWDQ	No	Yes	15	Fence and signs
City of Wayland WWTP	006	SR	0	14,000	GWQ	Yes	Yes	0	Fence and signs
Fontana Regional Plant No. 3	007	RI,SR	0	11,250	PTQ	No	Yes	91 RI basins 6 Citrus grove	Fence and signs--RI basins Signs--citrus grove
Pomona Water Reclamation Plant	008	SR	Gravity-\$12.16/1,000 m^3 Pressure-\$48.93/1,000 m^3[3]	16,933	PTQ	N/A	Yes	0	None
Whittier Narrows Water Reclamation Plant	009	RI	\$16.21/1,000 m^3	0	PTQ	N/A	Yes	0	Fence and signs
Palmdale Water Reclamation Plant	010	SR	\$4.05/1,000 m^3	0	PTQ,GWQ	N/A	No	0	Signs
Irvine Ranch Water District	011	SR	\$32.43-\$64.86/1,000 m^3	Not known	PTQ	N/A	Yes	0	None
City of Tulare WPCF	012	SR	City receives 25% of crop revenues	0	PTQ	Yes	Yes	0	Signs
City of Kerman WWTP	013	SR	\$1,000/yr for water \$181/ha/yr for land	194	PTQ	Yes	Yes	0	None
City of Manteca WWQCF	014	SR	\$10.71/ha/yr for land	10,000	PTQ,GWQ	Yes	No	0	None
El Dorado Hills WWTP	015	SR	\$100/month+\$31/1,000 m^3	Not known	PTQ,SWDQ	No	No	0	None
U.S. Army COE, WES Overland Flow Site	016	OF	0	Not known	None	Yes	Yes	400	Signs
Falkner WWTF	017	OF	0	360	SWDQ	Yes	Yes	0	Fence and signs
Easley Combined Utilities System Overland Flow Project	018	OF	0	2,326	None	Yes	No	15	Fence and signs
Town of Wareham WPCF	019	RI	0	0	SWDQ	Yes	Yes	30	Fence
Chatham WPCF	020	RI	0	0	OP	Yes	Yes	305	None
Town of Barnstable WPCF	021	RI	0	0	OP	Yes	Yes	30	Fence
Kendal/Crosslands Lagoon System	022	SR	0	3,630	PTQ	Yes	Yes	46	One field--fence and signs Other field--none
Landis Sewage Authority	023	RI	0	3,460	OP	No	Yes	0	None
Campbell Soup (Texas), Inc.	024	OF	0	Not known	SWDQ	No	Yes	30+	Fence
City of Coleman WWTP	025	SR	\$129.87/ha/yr for land	0	SWDQ	Yes	Yes	6	Fence and signs
City of Santa Anna WWTP	026	SR	Farmer pays pumping cost	727	OP	Being written	Yes	305	Fence
City of Winters WWTP	027	SR	\$8.09/ha/yr for entire site	3,000	OP	No	Yes	30	Fence
City of Sweetwater WPCP	028	SR	0	2,700	OP	N/A	Yes	15	Fence and signs

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[1] Does not include electrical usage by end users unless paid by authority.

[2] OP - Operating permit
PTQ - Preapplication treatment quality
SWDQ - Surface-water discharge quality
GWQ - Groundwater quality

[3] City of Pomona Water Department purchases water for \$9.26/1,000 m^3.

Key

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WWTF - Wastewater treatment facility
STP - Sewage treatment plant
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TABLE 12. LAND TREATMENT SYSTEMS INFORMATION (continued)

Facility Name	Site No.	Type of System	Land Treatment System Management	Surface Runoff Collected/ Diverted	Months System in Use[1]	Types of Crops	Crop Use	Who Harvests Crop?	Are Farming Practices Different?	Maximizing Crop Production or Wastewater Disposal
Village of Lake George WWTP	001	RI	Wastewater agency	Yes	1-12	Not applicable	-	-	N/A	N/A
North Branch Fire District No. 1 WPCF	002	SR	Wastewater agency	Yes	1-12	Maples, beeches, birches, white pine, spruce, fir	Not applicable	-	N/A	Wastewater
City of Hart WWTP	003	SR	Wastewater agency	Yes	4-11	Pine, hardwood, uncultivated	Not applicable	-	N/A	Wastewater
City of Fremont WWTP	004	SR	Wastewater agency	Yes	4-11	Alfalfa, oats, rye	Animal feed	Custom farmer	Yes	Wastewater
Village of Ravenna STP	005	SR	Wastewater agency	Yes	4-11	Uncultivated	Not applicable	-	N/A	Wastewater
City of Wayland WWTP	006	SR	Wastewater agency[2]	Yes	5-9	Alfalfa, timothy, grass, clover	Animal feed	Custom farmer	Yes	Wastewater
Fontana Regional Plant No. 3	007	RI SR	Wastewater agency and farmer	Yes	RI 1-12 SR 4-10	SR-grapefruits, oranges	Human consumption	Farmer	Yes	Crops
Pomona Water Reclamation Plant	008	SR	City of Pomona and end users	No	1-12	Landscape, alfalfa, tomatoes, corn, oats, barley, citrus	Human and animal consumption	Individual farmers	No	Crops
Whittier Narrows Water Reclamation Plant	009	RI	LACFCD	Yes	1-12	Not applicable	-	-	N/A	N/A
Palmdale Water Reclamation Plant	010	SR	Farmer	No	2-10	Alfalfa, oats	Animal feed	Farmer	No	Crops
Irvine Ranch Water District	011	SR	Wastewater agency, farmer and home owners assoc.	No	1-12	Tomatoes, peppers, corn, broccoli, cauliflower, landscape	Human consumption	Farmer	Yes	Crops
City of Tulare WPCF	012	SR	Farmer	No	1-12	Wheat, barley, oats, cotton, corn	Animal feed	Farmer	Yes	Crops
City of Kerman WWTP	013	SR	Farmer	No	1-12	Alfalfa, sugar beets, barley, oats, cotton, almonds	Human and animal consumption	Farmer	Yes	Crops
City of Manteca WWQCF	014	SR	Farmer	Yes	1-12	Barley, oats, corn	Cattle feed	Farmer	No	Wastewater
El Dorado Hills WWTP	015	SR	Golf course	No	1-12	Landscape	-	-	N/A	N/A
U.S. Army COE, WES Overland Flow Site	016	OF	Wastewater agency (COE)	Yes	1-12	Reed canary, fescue, perennial rye, Bermuda	Tested and discarded	COE	N/A	Wastewater
Falkner WWTP	017	OF	Wastewater agency	Yes	1-12	Harding grass, coastal Bermuda, reed canary, fescue	Left in field	Operator	N/A	Wastewater
Easley Combined Utilities System Overland Flow Project	018	OF	Wastewater agency and Clemson Univ.	Yes	1-12	Fescue, rye	Erosion control	Custom farmer	N/A	Wastewater
Town of Wareham WPCF	019	RI	Wastewater agency	Yes	1-12	Not applicable	-	-	N/A	N/A
Chatham WPCF	020	RI	Wastewater agency	Yes	1-12	Not applicable	-	-	N/A	N/A
Town of Barnstable WPCF	021	RI	Wastewater agency	Yes	1-12	Not applicable	-	-	N/A	N/A
Kendal/Crosslands Lagoon System	022	SR	Wastewater agency	No	1-12	Beeches, maples, poplar, oaks	Not applicable	-	N/A	Wastewater
Landis Sewage Authority	023	RI	Wastewater agency	Yes	1-12	Not applicable	-	-	N/A	N/A
Campbell Soup (Texas), Inc.	024	OF	Campbell Soup	Yes	1-12	Reed canary, fescue, red top, rye	Cattle feed	Custom farmer	N/A	Wastewater
City of Coleman WWTP	025	SR	Wastewater agency and farmer	Yes	1-12	Coastal Bermuda	Pasture	-	Yes	Wastewater
City of Santa Anna WWTP	026	SR	Wastewater agency and farmer	Yes	1-12	Alfalfa, Johnson grass	Pasture	-	Yes	Wastewater
City of Winters WWTP	027	SR	Farmer	Yes	1-12	Coastal Bermuda, Sudan grass	Pasture	-	Yes	Wastewater
City of Sweetwater WPCP	028	SR	Farmer	Yes	1-12	Coastal Bermuda, Sudan, Johnson, and Rescue grasses, oats, and wheat	Pasture, animal feed	Farmer	Yes	Crops

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[1] January = 1, December = 12
[2] Farmer to manage in future.

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three facilities, a groundwater quality permit was in effect. At five facilities, a surface-water discharge quality (NPDES) permit was in use. Three facilities operate under a dual permit system, with two utilizing a combined pretreatment quality and groundwater quality permit, and one having a combined pretreatment and surface discharge quality permit.

At the 22 facilities where an operation and maintenance manual would be of use in operating the land treatment system, 15 had a manual. In addition, only four of the 28 sites were currently operated differently from their design operation.

Of the sites visited, all of the rapid infiltration and overland flow systems were operated 12 months out of the year. It should be remembered, however, that the overland flow systems were all located in mild climates. Of the 18 slow-rate systems, only six are operated less than 12 months of the year. Of these, the citrus crop irrigation at facility 007 (Fontana, California Regional Plant) is included. In this case, however, as there is a rapid infiltration system also available, the slow-rate system is not operated during the colder months.

The types of crops grown and the ultimate use of the crops are also presented in Table 12 for the slow-rate and overland flow sites. Of the seven rapid infiltration sites visited, only the Chatham, Massachusetts facility had any major plant growth in the basins. This was just weed growth which had not been removed.

At the remaining sites (with the exception of Ravenna, Michigan), a wide range of crops is grown. At three sites, trees are irrigated but not harvested. At the Utica, Mississippi overland flow site, the vegetation was tested and discarded. In Falkner, Mississippi the vegetation was cut and left in the field. At the Easley, South Carolina overland flow site, the grass was baled; it is currently used only for erosion control, as permission has not yet been granted for it to be used as animal feed. At the remaining sites crops are grown and used for either human or animal consumption.

At the 13 facilities where the major objective of the land treatment system was crop production, the superintendent or foreman involved was queried as to whether or not the farming practices were different than at neighboring farms of equal soil type growing the same crop. At only three facilities were the farming practices the same as practices at neighboring farms. At the remaining sites, the farming practices were believed to be different. A description of the changes in farming practices is discussed in the trip reports contained in Appendix A.

Table 13 presents the land treatment system loading rates in terms of hydraulic, organic, suspended solids, and nutrients. The calculations are based primarily on information received during the site visits. These data may be compared to the typical loading rates presented in Table 1 in order to determine whether the actual hydraulic loading rates are in agreement with typical design standards. Based on this review, all hydraulic rates are in agreement with design loading rates.

CONFORMANCE OF SITES VISITED WITH BPWTT REQUIREMENTS

The criteria for Best Practicable Waste Treatment Technology (BPWTT) are set forth in 41 FR 6190 (February 11, 1976). The criteria for BPWTT for facilities employing land application techniques require that the groundwater resulting from the application of wastewater meet the standards for chemical quality (inorganic chemicals) and pesticides (organic chemicals) specified in the EPA National Interim Primary Drinking Water Regulations (40 CFR 141) in cases where the groundwater can be used for drinking water supply. In addition, the standards for chemical quality, pesticides, and microbial contamination are required in cases where the water is presently being used as a drinking water source. In cases where the water is not and will not be used for drinking water purposes, the EPA Regional Administrator, in conjunction with state officials, should establish the criteria on a case-by-case basis.

The criteria for BPWTT state that applicants for construction grant funds authorized by Section 201 of the 1977 Clean Water Act must have evaluated alternative waste treatment management techniques and selected the technique which will provide for the application of BPWTT. Only municipalities applying for construction grant funds after February 11, 1976 need consider BPWTT requirements.

Referring to Table 10, it can be seen that only two facilities have been operational less than four years, facility 017 (Falkner, Mississippi) and facility 018 (Easley, South Carolina). To the best of the operator's knowledge, neither facility had BPWTT requirements.

Regardless, to provide a prospective view of the current status of groundwater monitoring, Table 14 is presented. Basically, 11 of the 28 facilities visited had groundwater monitoring, and a variety of parameters at various frequencies were measured.

TABLE 13. LAND TREATMENT SYSTEM LOADING RATES

Facility Name	Site Number	Type of System	Hydraulic mm/wk	Hydraulic m/yr	Organic kg BOD_5/ha/yr	Suspended Solids kg SS/ha/yr	Nutrients kg NH_3-N/ha/yr	Nutrients kg NO_3-N/ha/yr	Nutrients kg T-P/ha/yr
North Branch Fire District No. 1 WPCF	002	SR	21.8	1.1	40.7	45.2	5.4	63.7	15.6[1]
City of Hart WWTF	003	SR	69.5	2.4	1,208	2,101	--	--	49.3[1]
City of Fremont WWTP	004	SR	76.2	2.6	316	817	--	--	87
Village of Ravenna STP	005	SR	--	1.2	--	--	--	--	--
City of Wayland WWTP	006	SR	42.2	1.1	287	--	--	--	--
Fontana Regional Plant No. 3	007	SR	54.6	1.6	1,623	1,247	472	5.9	410
Pomona Water Reclamation Plant	008	SR			Cannot be calculated				
Palmdale Water Reclamation Plant	010	SR	33.0	1.4	637	1,699	99.1	--	157[1]
Irvine Ranch Water District	011	SR			Cannot be calculated				
City of Tulare WPCF	012	SR	43.2	2.3	2,253	4,070	454	--	--
City of Kerman WWTP	013	SR	17.0	0.89	89	53	--	--	--
City of Manteca WWQCF	014	SR	58.4	3.0	1,471	1,382	445	16.9	--
El Dorado Hills WWTP	015	SR			Cannot be calculated				
Kendal/Crosslands Lagoon System	022	SR	40.6	2.1	320	428	219	--	149[1]
City of Coleman WWTP	025	SR	32.3	1.7	67.2	16.8	--	--	--
City of Santa Anna WWTP	026	SR	18.3	0.95	266	578	--	--	--
City of Winters WWTP	027	SR	76.2	4.0	1,775	2,365	--	--	--
City of Sweetwater WPCP	028	SR	45.7	1.2	215	132	--	--	--
Village of Lake George WWTP	001	RI	1,130	40.5	23,862	8,897	--	--	--
Fontana Regional Plant No. 3	007	RI	330	17.3	17,162	12,771	4,995	43.1	4,335
Whittier Narrows Water Reclamation Plant	009	RI	--	49.7[2]	--	--	--	--	--
Town of Wareham WPCF	019	RI	2,110	27.1	4,103	5,471	--	--	--
Chatham WPCF	020	RI	Winter 380 Summer 720	28.8	5,616	4,405	--	--	--
Town of Barnstable WPCF	021	RI	--	12.0	--	--	--	--	--
Landis Sewage Authority	023	RI	400	21.0	--	--	--	--	--
U.S. Army COE, WES Overland Flow Site	016	OF	63.5-254	3.3-13.2	87.6-349	139-555	55.0-222	--	39.3-158
Falkner WWTF	017	OF	17.8[3]	--	--		--	--	--
Easley Combined Utilities System	018	OF	Raw 119	--	11,810	10,982	944	79.9	172
Overland Flow Project			Pond 103-193	--	1,446-2,740	3,098-5,871	42.8-80.7	28.0-52.8	64.0-121
Campbell Soup (Texas), Inc.	024	OF	40.6	2.1	12,790	5,595	370[4]	--	160

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[1] Phosphorus measured as PO_4.
[2] Based on total water infiltration, not only reclaimed water.
[3] Design application rate.
[4] Total - N.

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility
WWTF - Wastewater treatment facility
STP - Sewage treatment plant
WWQCF - Wastewater quality control facility
WPCP - Water pollution control plant

TABLE 14. GROUNDWATER MONITORING DATA

Facility Name	Site Number	Type of System	Number of Wells	Groundwater Monitoring Parameters	Sample Frequency
Village of Lake George WWTP	001	RI	24	Wells installed by Rensselaer Polytechnic Institute for research purposes only	-
North Branch Fire District No. 1 WPCF	002	SR	6	pH, alkalinity, hardness, sulfate, chloride, ammonia-N, nitrate-N, phosphate	1/month when not frozen
City of Hart WWTP	003	SR	6[1]	Static water elevation, chloride, specific conductance, pH Hardness, alkalinity, ammonia-N, nitrate-N, phosphorus, MBAS, COD	1/month 1/year
City of Fremont WWTP	004	SR	32	Static water elevation, chloride, specific conductance pH, hardness, alkalinity, ammonia-N, nitrate-N, nitrite-N, phosphorus, sulfate	4/year 1/year
City of Wayland WWTP	005	SR	5	No samples are taken due to problems with wells. New wells are to be installed.	--
Whittier Narrows Water Reclamation Plant	009	RI	16$^+$	Major minerals, nitrogen compounds, COD, BOD, TDS, electrical conductance, pH, odor Trace metals, chlorinated hydrocarbons	4/year 1/year
Palmdale Water Reclamation Plant	010	SR	2	Various wastewater parameters measured in farmer's two irrigation wells	2/year
City of Manteca WWQCF	014	SR	9	Static water elevation, ammonia-N, nitrite-N, nitrate-N	4/year
Easley Combined Utilities System Overland Flow Project	018	OF	5	Groundwater monitoring for research purposes only	-
Kendal/Crosslands Lagoon System	022	SR	7	Static water elevation, pH, ammonia-N, nitrite-N, nitrate-N, phosphate, fecal coliforms	4/year
Landis Sewage Authority	023	RI	3	Water table elvation	Continuous

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[1] Four local domestic wells also monitored.

LAND TREATMENT OPERATION PROCEDURES

The majority of the sites visited were adequately operated and their performance is believed acceptable as their operational practices are within the standard guidelines. Only one facility, Winters, Texas, appeared to have major operational difficulties. These difficulties appeared due to the constraints placed on the system due to poor design. In general, a land treatment system should be well operated since operation of the system is uncomplicated, particularly for the slow-rate and rapid infiltration systems. In fact, with a slow-rate system there are few parameters that can be controlled by the facility operator. For example, the yearly application rate is fixed by the amount of available land. The application rate can be increased by taking land out of service. However, it cannot be decreased unless extra land is available or the possibility for surface discharge exists. The operational aspect involves how much wastewater should be applied in order to match the required yearly amount of wastewater generated.

The operation of a rapid infiltration system is even simpler as there is normally no storage, and the amount of wastewater generated daily must be applied to the rapid infiltration beds the same day. The operation, therefore, consists of rotating the beds based, typically on visual observation, and insuring that the beds are adequately maintained so that there is always sufficient capacity to handle the influent wastewater.

An overland flow system has the greatest potential for operator control. The operator can vary the time over which the specified amount of wastewater is applied, and can, to some degree, take plots in and out of service to meet the required demand, thereby controlling the hydraulic loading rate, unless, of course, the system is overloaded.

In terms of operational strategy and process control, very little is done by the operators of land treatment systems. This is not to say that the systems are not well operated, but it appears that once the operator gets in a "groove" he is content to stay with this mode of operation. Given this type of steady-state operation, the need for process control is minimized. For example, it is commonly stated that the amount of nitrification and denitrification in a rapid infiltration system can be controlled by the dosing schedule maintained. Typical operations in the field do not attempt to maximize nitrification/denitrification. This is not attempted due to the practical difficulties involved in operating the system in this mode, and the fact that the operator has no apparent need to run the system in this mode. In addition, this sort of exercise may be possible in a laboratory, but the process control necessary on a large-scale system is extremely difficult, if not impossible.

An additional process control item often discussed is the effect of loading cycles on the hydraulic capacity of an infiltration bed. Typically, in the field the rate and amount of wastewater applied to the beds are based on experience; experiments are not conducted to find the effect of various dosing patterns on the subsequent infiltration potential of the basin. Similarly, for the overland flow system, mention is made of the effect of a resting period to allow for nitrification. Typically, the process controls necessary to make these allowances are not measured in actual field installations.

One area of interest involves the effects of seasonal variation on operation and performance of land treatment systems. Based on the site visits, there appeared to be minimal problems associated with winter operation of the rapid infiltration systems. Specifically, facilities 001, 019, 020, and 021 (Lake George, Chatham, Barnstable, and Wareham) are located in areas subject to subfreezing winter temperatures and no major problems were associated with winter operation.

Two of the slow-rate land treatment systems in temperate regions (North Branch Fire District No. 1 and Kendal/Crosslands) operate 12 months of the year. The four slow-rate facilities located in Michigan, however, only operate part-time during the winter. The two facilities that operate during the winter months stop spray irrigation when the temperature reaches a specified low point: -17.8°C (0°F) for the North Branch Fire District, and -6.7°C (20°F) for the Kendal/Crosslands Lagoon System. As would be expected, the major operational problem during the winter months is freezing of the spray nozzles and lines. Particular care must be taken to minimize the potential for problems. A further description of winter operational problems is contained in the trip reports in Appendix A. The effect of winter conditions on an overland flow treatment system cannot be assessed as no facilities operating under winter conditions were visited.

Basically, operation of slow-rate and rapid infiltration systems is similar in that wastewater is applied to an area as necessary. In the case of a slow-rate system irrigating crops, "necessary" infers that the crop requires irrigation. Conversely, "necessary," in terms of a slow-rate system for a noncultivated area or a wooded area, is similar to the operation of a rapid infiltration system in that wastewater is applied to the area most able to accept the additional hydraulic loading. Rotation of the areas to be irrigated is based on visual observation and experience.

For an overland flow land treatment system, the operational strategy for two of the facilities cannot be assessed as the Utica and Easley facilities were research operations, and therefore, on strict application schedules. These schedules allowed varying amounts of wastewater to be applied to plots for varying time periods so that a correlation between various parameters could be attained. In addition, the Falkner, Mississippi site is typically run more as a slow-rate system than as an overland flow system, and little can be gained in terms of insight into the operational strategies. This leaves facility 024 (Campbell Soup, Paris, Texas) as the only acceptable operating plant. The operation of this facility follows a strict schedule of rotation by which wastewater is applied for six to eight hours per day, followed by a rest period the remainder of the day. Beds are taken out of service for crop harvesting purposes only. Campbell Soup has spent a lot of time and effort in defining the optimum conditions for the overland flow system, specific to their wastewater. This sort of effort could not be expected for a municipal facility, particularly a smaller municipal facility.

Sites visited ranged in capacity from 0.0009 m^3/s (20,000 gpd) for facility 016 (Utica, Mississippi) to 0.701 m^3/s (16 mgd) at facility 009 (Whittier Narrows, California). For the slow-rate and rapid infiltration systems, no discernible difference in operation and maintenance was evident as a function of flow rate. A discernible difference was noticed between the operation and maintenance of the smaller overland flow facilities as compared to the Campbell Soup facility. At this facility, the operational staff was knowledgeable, and kept matters on the right track. At the smaller Falkner, Mississippi facility (017), although there were no operational problems, there were no rigid operational guidelines. No comparison can be drawn, however, by comparing the sophisticated industrial wastewater treatment facility to the extremely small rural overland flow treatment facility.

LAND TREATMENT MAINTENANCE PRACTICES

Regardless of the type of land treatment system, the equipment utilized should not be appreciably different than equipment used at the wastewater preapplication treatment facility, with the possible exception of irrigation equipment. Therefore, a reasonably experienced treatment plant operator or maintenance man should not encounter any major difficulties with the land treatment equipment that is installed. Typically, the systems consist of valves, piping, pumps, and possibly controllers, equipment with which maintenance people are well aquainted.

In fact, an appealing virtue of a land treatment system is its overall simplicity and lack of maintenance requirements. This makes the land treatment system particularly effective for smaller flows where the system can consist of a simple preapplication treatment step, such as an oxidation pond, followed by the land treatment system. This type of system has extremely low maintenance, operator and energy requirements, yet can produce a good quality effluent with minimal environmental impact.

The land treatment systems, in general, have the same maintenance problems as wastewater treatment plants, i.e., pumps and electric control valves. None of these maintenance problems, however, are extremely difficult to handle or cause major problems. One problem associated with the maintenance of a land treatment system with which the operator may not be familiar is the wastewater distribution system, particularly if the system is a spray application type. With a small amount of training, however, the maintenance of these items is not believed to be a problem. In addition, in many cases the application equipment will be operated and maintained by a private farmer. At none of the facilities visited did the application equipment in use cause major maintenance problems.

BUFFER ZONES

The interaction between the public sector and the land treatment system was viewed in two areas, the first being the presence of a buffer zone, and the second, whether or not the public was allowed access to the site. At 11 of the 22 sites, there were no buffer zones between the land treatment system and the neighboring properties. These 11 sites include sites utilizing both spray irrigation and surface application techniques. In terms of public access, there are basically three modes of control. The first is a fence, with or without signs, for positive control; the second uses signs for control; and in the third mode, no attempt is made at control. At 15 of the sites, control is by means of a fence, both with or without signs. At four sites, public access is controlled utilizing signs stating the use of reclaimed water. At nine sites, the public has access to the land treatment portion of the facility. This is not to say, however, that the operators desire people to come in contact with the wastewater. In addition, at two of the facilities in Texas, fences are only used for control of livestock and were not intended to keep the public from contacting the reclaimed water.

A neighbor interview survey was conducted, where appropriate, during the site visits to quantify the effect of the land treatment systems on the neighbors. There were no reported problems with drifting aerosol or mist, and the majority of complaints involved odors or mosquitoes. The odors may, however, be involved with either sewage or sludge treatment or land application, and are hard to track down. The complaints of bugs and mosquitoes are typically related to water impoundments, and, at various locations, attempts are made through local agencies to minimize the problem.

MANAGEMENT AND STAFFING STRATEGIES

A variety of management techniques for the land treatment system are possible. This is particularly true for the slow-rate system as opposed to the rapid infiltration and overland flow systems which are typically operated by the wastewater treatment agencies except in the case of the Whittier Narrows facility. Of the 18 different slow-rate systems visited, the land treatment system was managed by the wastewater agency at six facilities. At nine facilities, the land treatment system was managed by the end user, typically a farmer. In three cases management was carried out by the wastewater agency and the farmer jointly.

Slow-Rate Systems

The management of a slow-rate system can take one of three general directions. The first alternative is a land treatment facility which is owned and operated by the wastewater treatment agency. The second potential management scheme is when the wastewater treatment plant staff and the land treatment system staff are two separate entities, each managing their own system. The third situation, and possibly the most common, is a position somewhere between the first and second schemes. In this case, some of the operations of the land treatment system are carried out by the preapplication treatment personnel, and some are carried out by the farmer.

A further complication exists when discussing management strategies. There is a difference between land treatment and land application, based on the degree of preapplication treatment. For the land application system, the wastewater is typically pretreated to a high degree, and management of a land application system is very similar to the management of a normal irrigation system. Two facilities of this type were visited, i.e., facilities 008 and 011 (Pomona Water Reclamation Plant and Irvine Ranch Water District). The remainder of this section is more applicable to the land treatment systems than the land application systems.

Given the three choices of system management, the next question is which of these alternative methods is most effective. Based on data presented in Section 7 it is shown that the most expensive land treatment systems are those which were owned and operated by the wastewater treatment agency. This is not surprising as the facility must supply the labor necessary to operate the system. In terms of dollars per volume of wastewater treated, however, either the second or third management strategy has merit in that some of the normal costs of operation of the land treatment system can be defrayed by the farmer who is operating the system. This decreases the apparent total cost of wastewater treatment and disposal. Therefore, the second or third method of management is suggested where possible. For large systems, however, the second and third management strategies may be difficult or impractical, and therefore a publicly operated system may be desirable.

The key point to remember is the need for a close working relationship between the preapplication treatment and land treatment management. In this way, any potential problems can be worked out and both parties will gain the greatest advantage from the relationship. An example of this can be seen in the trip report for facility 028 (Sweetwater, Texas).

There can be a particular problem with staffing a slow-rate land treatment system. This problem is most acute where treatment plant personnel are totally or partially involved in the operation of the land treatment facility. The operation of a land treatment facility requires expertise that is partially different from the operation of a preapplication treatment facility. Therefore, where possible, operators who have previous farming experience should be hired to fill these positions. The staffing requirement is an impetus toward having a farmer operate the slow-rate land treatment system, as he would be the person most able to run and operate a farm in the most efficient manner.

Rapid Infiltration Systems

The management strategy for a rapid infiltration system is simpler than the slow-rate system as the rapid infiltration systems will typically be operated by the treatment plant personnel. Based on observations during the site visits, it is noted that the rapid infiltration beds require minimal operational attention, and the major labor requirement is related to bed maintenance.

The amount of labor associated with rapid infiltration bed maintenance is a function of the degree of preapplication treatment. This concept is discussed in a subsequent subsection, and the OWRT labor requirements presented in Figure 4 are believed to be a fair starting point toward estimating the required staffing. Additions or subtractions from these labor requirements, however, should be made based on the degree of preapplication treatment. Treatment plant operations staff should have the expertise required to operate the land treatment system. Minimal training above and beyond conventional wastewater treatment training should be required.

Overland Flow Systems

Management of an overland flow system, like a rapid infiltration system, will be performed by the wastewater treatment agency. Unlike a rapid infiltration system, however, an overland flow system requires a higher degree of operator training. As the concepts necessary for operating an overland flow system are different from those typically taught in a wastewater operators training course, additional operator training is recommended.

LAND TREATMENT SYSTEMS STAFFING LEVELS

During the site visits, the staffing requirements for the operation and maintenance of the preapplication treatment and land treatment portions of the facility were collected. These data are presented in Table 15 which also presents data on the number of shifts per day and days per week that the preapplication and land treatment systems are staffed. In addition, the table presents the number of man-days per week which are spent in conjunction with both preapplication and land treatment. Based on the amount of wastewater which is land applied (not necessarily the treatment plant flow rate), the staffing requirement in terms of man-days per 1,000 cubic meters has been calculated for both the preapplication and the land treatment systems.

A review of Table 15 indicates that most of the treatment plants were manned one shift per day. Some of the larger facilities were manned either two or three shifts per day, however. Typically, plants were manned seven days per week. In terms of man-days per 1,000 cubic meters necessary for preapplication treatment, facility 011 (Whittier Narrows Reclamation Plant) required the least amount of operation and maintenance time, requiring only 0.04 man-days per 1,000 cubic meters. Conversely, facility 020 (Chatham, Massachusetts) had the highest operation and maintenance needs as it required 4.68 man-days per 1,000 cubic meters.

The land treatment system associated with facility 027 (City of Winters, Texas) was the least labor-intensive as the operator reported that he spent no time in conjunction with the land treatment system. The most labor-intensive systems are facility 016 (U.S. Army Corps of Engineers Overland Flow Site, Utica, Mississippi), which required 9.18 man-days per 1,000 cubic meters, and facility 018 (Easley, South Carolina), which required 2.07 man-days per 1,000 cubic meters. These are research facilities, however, and not typical of an operating facility. The next highest nonresearch system is facility 017 (Falkner, Mississippi), which required 1.72 man-days per 1,000 cubic meters.

TABLE 15. PREAPPLICATION TREATMENT AND LAND TREATMENT STAFFING

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preapplication Treatment System				Land Treatment System[1,2]				Total System
				Shifts/ Day	Days/ Week	Man-Days/ Week	Man-Days/ 1,000 m^3	Shifts/ Day	Days/ Week	Man-Days/ Week	Man-Days/ 1,000 m^3	Man-Days/ 1,000 m^3
Village of Lake George WWTP	Lake George, NY	001	0.0280	1	7	13.1[3]	0.77	1	7	11.65[3]	0.69	1.46
North Branch Fire District No. 1 WPCF	West Dover, VT	002	0.0049	1	7	4.4	1.48	1	5	3.9	1.32	2.80
City of Hart WWTF	Hart, MI	003	0.0267	1	7	6.5	0.40	1	5	2.5	0.15	0.55
City of Fremont WWTP	Fremont, MI	004	0.0133	1	5	6.3	0.78	1	5	2	0.25	1.03
Village of Ravenna STP	Ravenna, MI	005	0.0032	1	7	1.3	0.67	1	5	0.13	0.07	0.74
City of Wayland WWTP	Wayland, MI	006	0.0110	1	5	2.0	0.30	1	7	0.8	0.12	0.42
Fontana Regional Plant No. 3	Fontana, CA	007	0.0438	1	7	5.0	0.19	1	7	5.0	0.19	0.38
Pomona Water Reclamation Plant	Pomona, CA	008	0.3505[4]	3	7	54[3,5]	0.25	1	7	0.9[3]	0.006	0.26
Whittier Narrows Water Reclamation Plant	El Monte, CA	009	0.7010	1	7	15[3,5]	0.04		Not applicable			----
Palmdale Water Reclamation Plant	Palmdale, CA	010	0.0811	1	7	9.4	0.19	1	5	0.6	0.01	0.20
Irvine Ranch Water District	Irvine, CA	011	0.3505	3	7	63	0.30	2	7	30	0.14	0.44
City of Tulare WPCF	Tulare, CA	012	0.1490	1	7	28.4	0.32	1	7	0.6	0.007	0.33
City of Kerman WWTP	Kerman, CA	013	0.0228	1	7	9.8	0.71	1	5	0.3	0.02	0.73
City of Manteca WWQCF	Manteca, CA	014	0.1008	3	7	27	0.44	1	7	3	0.05	0.49

[1] Yearly averages.
[2] 1,000 m^3 x 3.785 = million gallons
[3] Does not include superintendent's time.
[4] Flow based on yearly average, land treatment flow yearly average = 0.173 m^3/s.
[5] Does not include sludge handling.
[6] Five-day average production flow. Yearly average flow = 0.1796 m^3/s. Man-days requirements are based on five-day average flow rate.
[7] Does not include superintendent or chief operator's time.
[8] Flow based on yearly average, accounting for surface discharge = 0.0123 m^3/s.

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility
WWTF - Wastewater treatment facility
STP - Sewage treatment plant
WWQCF - Wastewater quality control facility
WPCP - Water pollution control plant

TABLE 15. PREAPPLICATION TREATMENT AND LAND TREATMENT STAFFING

(continued)

Facility Name	Facility Location	Site No.	Current Flow Rate[1] (m^3/s)	Preapplication Treatment System: Shifts/ Day	Preapplication Treatment System: Days/ Week	Preapplication Treatment System: Man-Days/ Week	Preapplication Treatment System: Man-Days/ 1,000 m^3	Land Treatment System[1,2]: Shifts/ Day	Land Treatment System[1,2]: Days/ Week	Land Treatment System[1,2]: Man-Days/ Week	Land Treatment System[1,2]: Man-Days/ 1,000 m^3	Total System Man-Days/ 1,000 m^3
El Dorado Hills WWTP	El Dorado Hills, CA	015	0.0197	1	7	9.4	0.79	1	5	0.6	0.05	0.84
U.S. Army COE, WES Overland Flow Site	Utica, MS	016	0.0009		Not applicable			1	5	5	9.18	9.18
Falkner WWTF	Falkner, MS	017	0.0012	1	5	1.3	1.72	1	5	1.3	1.72	3.44
Easley Combined Utilities System Overland Flow Project	Easley, SC	018	0.0044		Not applicable			1	5	5.5	2.07	2.07
Town of Wareham WPCF	Wareham, MA	019	0.0140	1	7	20	2.36	1	5	0.8	0.09	2.45
Chatham WPCF	Chatham, MA	020	0.0035	1	7	9.9	4.68	1	7	0.5	0.24	4.92
Town of Barnstable WPCF	Hyannis, MA	021	0.0252	1	7	10.8	0.71	1	7	2.7	0.18	0.89
Kendal/Crosslands Lagoon System	Kennett Square, PA	022	0.0022	1	5	2.5	1.88	1	5	1.3	0.94	2.82
Landis Sewage Authority	Vineland, NJ	023	0.1753	1	7	22	0.21	1	7	16	0.15	0.36
Campbell Soup (Texas), Inc.	Paris, TX	024	0.2234[6]		Not applicable			3	7	40[7]	0.30	0.30
City of Coleman WWTP	Coleman, TX	025	0.0175[8]	1	7	4.3	0.41	1	7	0.7	0.09	0.50
City of Santa Anna WWTP	Santa Anna, TX	026	0.0033	1	7	1.3	0.65	1	5	1.0	0.50	1.15
City of Winters WWTP	Winters, TX	027	0.0131	1	5	1.0	0.13	1	0	0	0	0.13
City of Sweetwater WPCP	Sweetwater, TX	028	0.0438	2	7	18.8	0.71	1	7	0.9	0.03	0.74

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[1] Yearly averages.
[2] 1,000 m^3 x 3.785 = million gallons
[3] Does not include superintendent's time.
[4] Flow based on yearly average, land treatment flow yearly average = 0.173 m^3/s.
[5] Does not include sludge handling.
[6] Five-day average production flow. Yearly average flow = 0.1796 m^3/s. Man-days requirements are based on five-day average flow rate.
[7] Does not include superintendent or chief operator's time.
[8] Flow based on yearly average, accounting for surface discharge = 0.0123 m^3/s.

Key

WWTP - Wastewater treatment plant
WPCF - Water pollution control facility
WWTF - Wastewater treatment facility
STP - Sewage treatment plant
WWQCF - Wastewater quality control facility
WPCP - Water pollution control plant

It is felt that the most accurate data can be presented by the total system (preapplication and land treatment) operation and maintenance labor requirements. This is because treatment plants do not typically keep track of the amount of time spent in conjunction with operation and maintenance of preapplication vs land application portions of the facility. The least labor-intensive system was once again the Winters Wastewater Treatment Facility which required only 0.13 man-day per 1,000 cubic meters. Aside from the U.S. Army Corps of Engineers site, the most labor-intensive treatment system was the Chatham, Massachusetts Water Pollution Control Facility which required 4.92 man-days per 1,000 cubic meters.

From "Water Reuse and Recycling," volume 2, OWRT/RU-79/2 (U.S. Department of the Interior, 1979), data were obtained for the labor requirements for the three types of land treatment systems. The labor requirements are presented in Tables 16, 17, and 18. These three tables also include data on electrical consumption and maintenance requirements, which will be used in a later section. For the three different treatment plant sizes, the labor requirements were then translated into man-days per 1,000 cubic meters of wastewater. These data were then plotted for the three different types of systems and are shown on Figures 3, 4, and 5. For comparison purposes, the data from the sites surveyed are also presented on the figures. It should be noted that the smallest flow given in the OWRT report was 0.044 m^3/s (1.0 mgd), and due to the nonlinear nature of the data, the curve from 0.044 m^3/s (1.0 mgd) to 0.0004 (0.01 mgd) was extrapolated, based on the nature of the curve.

Figure 3 shows that only three treatment facilities appear above the extrapolated line, i.e., facilities 002, 004, and 022. The similarity between these facilities is that, in each case, all operation and maintenance is carried out by treatment plant personnel. Two other facilities (facilities 011 and 026) appear very close to the OWRT data. Facility 011 is the Irvine Ranch Water District dual water supply system, and therefore requires the high labor requirement. Facility 026 (City of Santa Anna, Texas) is a system in which all irrigation is performed by city personnel. The remaining 11 facilities appear substantially below the curve, and once again appear to reflect the fact that labor is supplied by someone other than the sewage disposal authority, resulting in low labor requirements.

In Figure 4, it is seen that four facilities (facilities 007, 011, 021, and 023) appear above the OWRT curve. Of these

TABLE 16. SLOW-RATE LAND TREATMENT SYSTEMS OPERATION AND MAINTENANCE COST COMPONENTS[1,2]

	Plant Size		
	0.044 m^3/s (1.0 mgd)	0.438 m^3/s (10 mgd)	2.19 m^3/s (50 mgd)
Electrical Consumption Cost[3]	$20,980	$209,760	$1,048,800
Maintenance Materials[4]	$8,580	$64,990	$235,300
Labor Cost[5]	$26,080	$176,700	$594,800
Total Yearly Cost	$55,640	$451,450	$1,878,900

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[1] All costs escalated to second quarter 1980 from September 1977 base utilizing EPA's Operation and Maintenance Cost Indices.

[2] Costs are from "Water Reuse and Recycling," Volume 2, Evaluation of Treatment Technology, for moderately favorable conditions and include the following components: force mains, monitoring wells, center pivot spray, storage, and distribution pumping.

[3] Electricity at $0.04/kwh escalated by 1.38 factor.

[4] Maintenance materials escalated by 1.34 factor.

[5] Labor at $10/hr escalated by 1.21 factor.

TABLE 17. RAPID INFILTRATION LAND TREATMENT SYSTEMS OPERATION AND MAINTENANCE COST COMPONENTS[1,2]

	Plant Size		
	0.044 m^3/s (1.0 mgd)	0.438 m^3/s (10 mgd)	2.19 m^3/s (50 mgd)
Electrical Consumption Cost[3]	\$8,890	\$88,600	\$442,980
Maintenance Materials[4]	\$1,210	\$6,430	\$27,870
Labor Cost[5]	\$11,710	\$52,800	\$194,020
Total Yearly Cost	\$21,810	\$147,830	\$664,870

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[1] All costs escalated to second quarter 1980 from September 1977 base utilizing EPA's Operation and Maintenance Cost Indices.

[2] Costs are from "Water Reuse and Recycling," Volume 2, Evaluation of Treatment Technology, for moderately favorable conditions and include the following components: distribution pumping, monitoring wells, force mains, and infiltration basins.

[3] Electricity at \$0.04/kwh escalated by 1.38 factor.

[4] Maintenance materials escalated by 1.34 factor.

[5] Labor at \$10/hr escalated by 1.21 factor.

TABLE 18. OVERLAND FLOW LAND TREATMENT SYSTEMS OPERATION AND MAINTENANCE COST COMPONENTS[1,2]

	Plant Size		
	0.044 m^3/s (1.0 mgd)	0.438 m^3/s (10 mgd)	2.19 m^3/s (50 mgd)
Electrical Consumption Cost[3]	\$8,890	\$88,600	\$442,980
Maintenance Materials[4]	\$10,320	\$61,240	\$218,690
Labor Cost[5]	\$22,190	\$112,780	\$387,120
Total Yearly Cost	\$41,400	\$262,620	\$1,048,790

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[1] All costs escalated to second quarter 1980 from September 1977 base utilizing EPA's Operation and Maintenance Cost Indices.

[2] Costs are from "Water Reuse and Recycling," Volume 2, Evaluation of Treatment Technology, for moderately favorable conditions and include the following components: force mains, distribution pumping, monitoring wells, distribution, runoff collection, chlorination/discharge, and storage.

[3] Electricity at \$0.04/kwh escalated by 1.38 factor.

[4] Maintenance materials escalated by 1.34 factor.

[5] Labor at \$10/hr escalated by 1.21 factor.

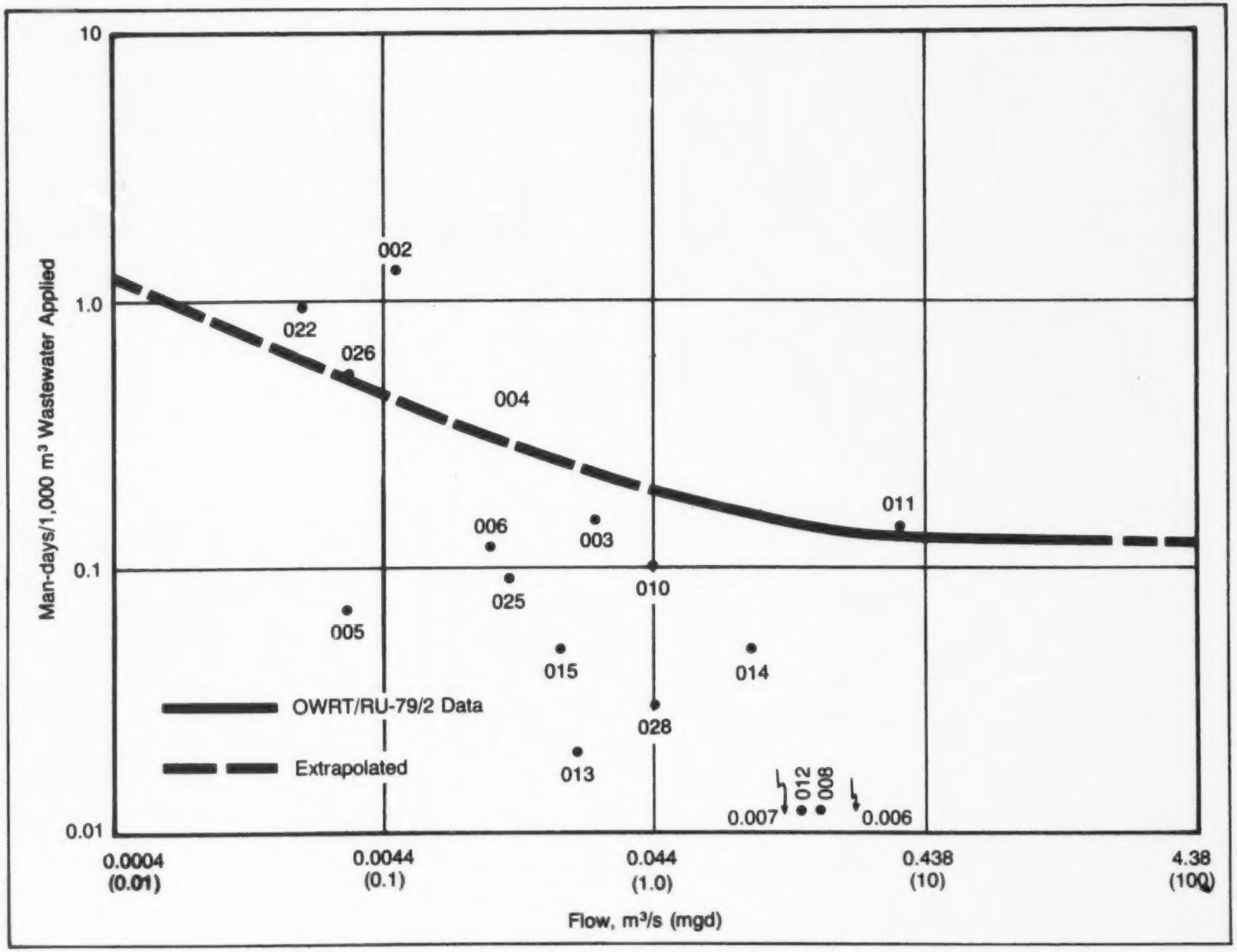

Figure 3. Slow-rate land treatment staffing.

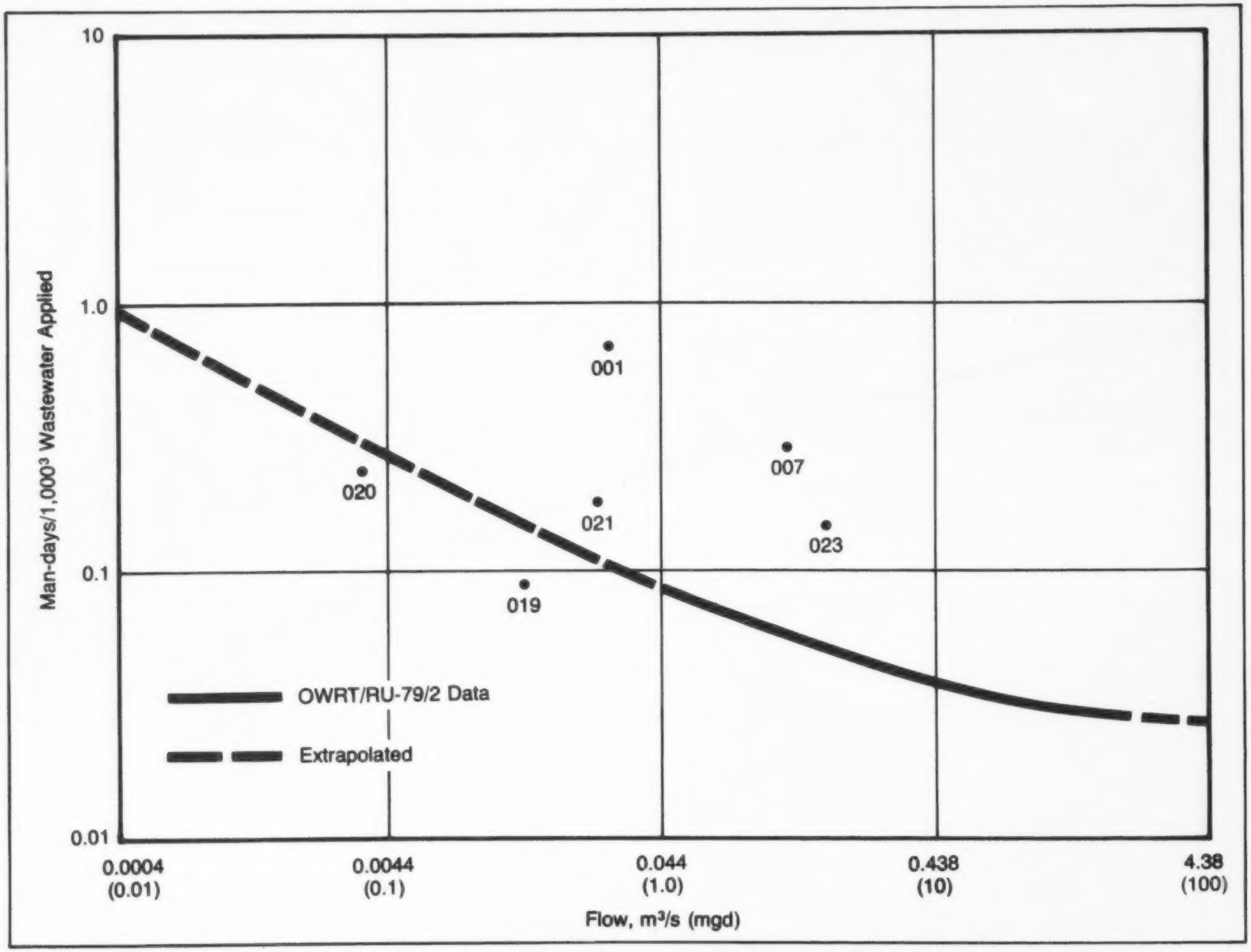

Figure 4. Rapid infiltration land treatment staffing.

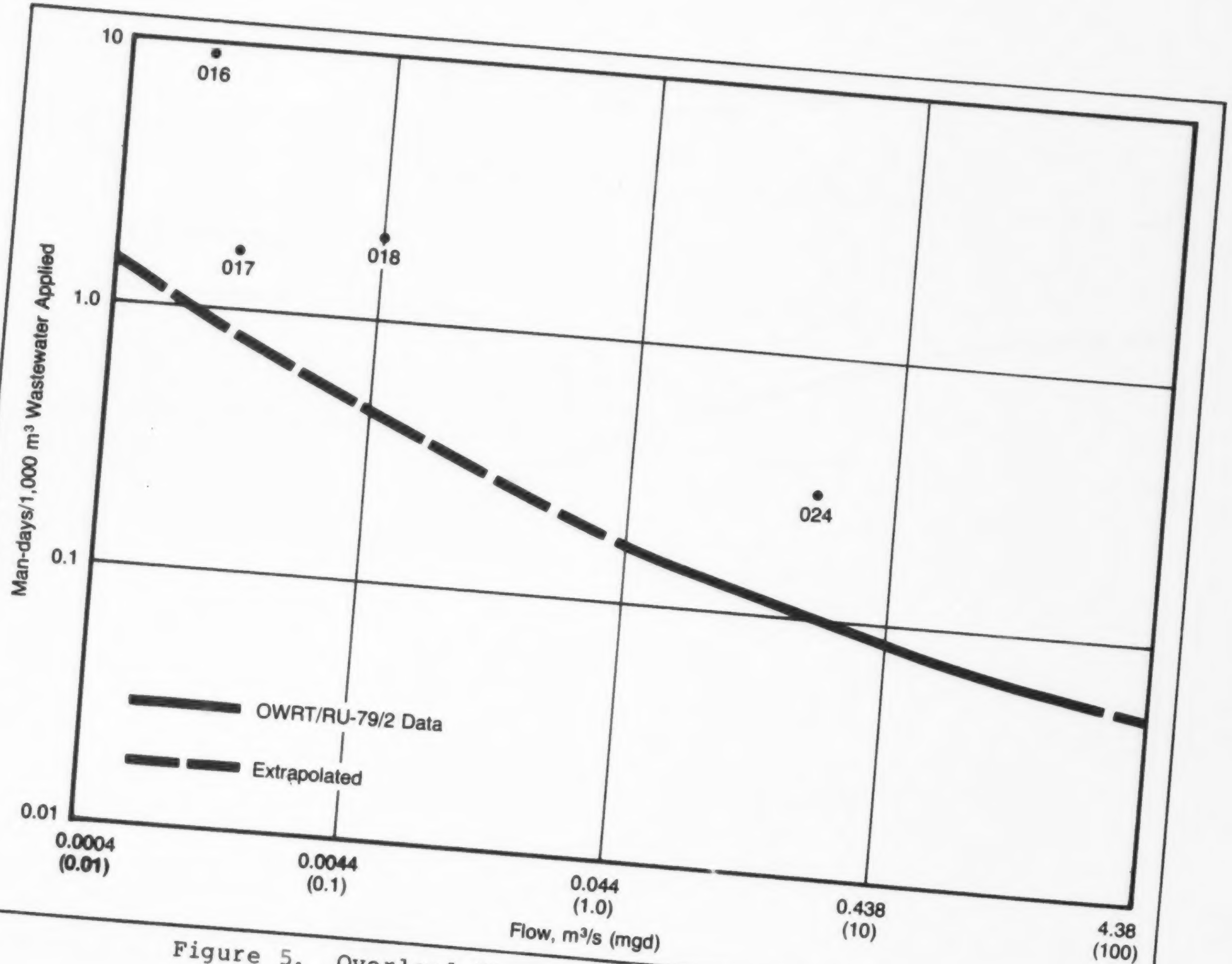

Figure 5. Overland flow land treatment staffing.

four, three utilize primary pretreatment, and the fourth an intermediate level of pretreatment. The two facilities which appear below the OWRT staffing line are secondary pretreatment facilities, and therefore less operation and maintenance is required for the land treatment system. For comparison purposes, it should be remembered that the OWRT curves are based on moderately-favorable conditions which, for the rapid infiltration system, consist of a preapplication treatment system utilizing a two-stage aerated lagoon which would be capable of producing an intermediate to secondary quality effluent.

The data in Figure 5 show that all four of the overland flow facilities had labor requirements in excess of OWRT data. It should be remembered that facilities 016 and 018 are research-related facilities, and facility 024 (Campbell Soup (Texas), Inc.) is an industrial wastewater treatment facility where the staffing requirements are not comparable to municipal wastewater application.

The data in Table 19 are presented to illustrate the effect of preapplication treatment on the subsequent staffing requirements for the land treatment portion of the system. As insufficient data exist to make comparisons of overland flow systems, only slow-rate and rapid infiltration systems will be discussed. Utilizing the data presented in Table 19, average operation and maintenance man-days per 1,000 cubic meters of wastewater applied can be calculated for preapplication and land application treatment, as well as the total system operation and maintenance labor requirement. The effect of preapplication treatment on land treatment staffing and total staffing can be assessed by rating the average labor requirements per level of preapplication treatment. In order of increasing staffing, the preapplication treatment labor requirements for slow-rate land treatment would be:

1. Tertiary treatment with disinfection.

2. Intermediate treatment with disinfection.

3. Intermediate treatment.

4. Secondary treatment.

5. Secondary treatment with disinfection.

Similarly, the labor requirements, in order of increasing staffing, for slow-rate land treatment are:

1. Secondary treatment.

2. Tertiary treatment with disinfection.

TABLE 19. STAFFING REQUIREMENTS AS A FUNCTION OF DEGREE OF PREAPPLICATION TREATMENT AND LAND TREATMENT SYSTEM TYPE

Degree of Preapplication Treatment	Type of Land Treatment System	Site Number	Flow Rate[1] (m^3/s)	Preapplication Treatment Staffing[2] Man-days/1,000 m^3	Land Treatment Staffing Man-days/1,000 m^3	Total Treatment Staffing Man-days/1,000 m^3
Preliminary	OF	024	0.2234[3]	----	0.30	0.30
Primary	RI	021	0.0252	0.71	0.18	0.89
		007[4]	0.1270	0.19	0.19	0.38
		023	0.1753	0.21	0.15	0.36
Intermediate	SR	005	0.0032	0.67	0.07	0.74
		026	0.0033	0.65	0.50	1.15
		027	0.0131	0.13	----	0.13
		003	0.0267	0.40	0.15	0.55
		010	0.0811	0.19	0.01	0.20
		014	0.1008	0.44	0.05	0.49
		012	0.1490	0.32	0.007	0.33
	RI	001	0.0280	0.77	0.69	1.46
	OF	016	0.0009	----	9.18	9.18
Intermediate with disinfection	SR	006	0.0110	0.30	0.12	0.42
	OF	017	0.0012	1.72	1.72	3.44
		018	0.0044	----	2.07	2.07
Secondary	SR	015	0.0197	0.79	0.05	0.84
		013	0.0228	0.71	0.02	0.73
		028	0.0438	0.71	0.03	0.74
	RI	020	0.0035	4.68	0.24	4.92
Secondary with disinfection	SR	022	0.0022	1.88	0.94	2.82
		002	0.0049	1.48	1.32	2.80
		004	0.0133	3.26	1.03	4.29
		025	0.0175	0.41	0.09	0.50
	RI	019	0.0140	2.36	0.09	2.45
Tertiary with disinfection	SR	008	0.3505	0.25	0.006	0.26
		011	0.3505	0.30	0.14	0.44
	RI	009	0.7010	0.04	----	0.04

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[1] $m^3/s \times 22.8245$ = mgd

[2] Man-days/1,000 $m^3 \times 3.7854$ = man-days/million gallons.

[3] Five-day average production flow. Yearly average flow = 0.1796 m^3/s. Man-days requirements are based on five-day average flow rate.

[4] System is SR also, however, costs reflect RI system.

3. Intermediate treatment with disinfection.

4. Intermediate treatment.

5. Secondary treatment with disinfection.

Based on the data, it appears that the degree of preapplication treatment does not appear to materially affect the operation and maintenance labor required for a slow-rate land application system. When the total labor costs for the slow rate and preapplication treatment systems are rated, the tertiary plant with disinfection is the least expensive, followed by intermediate treatment with disinfection, intermediate, secondary, and finally, secondary treatment with disinfection; there is no discernible pattern.

Utilizing the data in Table 19, a similar exercise can be conducted for rapid infiltration systems. Discounting the data for the tertiary plant with disinfection (facility 009, Whittier Narrows), the order of increasing preapplication labor requirements for rapid infiltration is:

1. Primary treatment.

2. Intermediate treatment.

3. Secondary treatment with disinfection.

4. Secondary treatment.

The order of increasing land treatment labor requirements for rapid infiltration is:

1. Secondary treatment with disinfection.

2. Primary treatment.

3. Secondary treatment.

4. Intermediate treatment.

The total labor requirements, in order of increasing staffing, for rapid infiltration systems are:

1. Primary treatment.

2. Intermediate treatment.

3. Secondary treatment with disinfection.

4. Secondary treatment.

Although this quick survey only includes six facilities, the costs seem to indicate that the land application labor requirements are a function of the degree of preapplication treatment. This is to be expected due to the increased solids loading resulting from decreased pretreatment.

When a comparison is made of the labor requirements for the slow-rate vs the rapid infiltration systems for the same degree of preapplication treatment, a very general conclusion can be reached that the slow-rate system typically utilizes less labor than the rapid infiltration system. No definite conclusion can be made, however, because of the minimal amount of data used to draw this conclusion. In fact, these conclusions are very general indeed and should not be taken as universal due to the widely varying conditions which each data point reflects.

EFFECTS OF PREAPPLICATION TREATMENT ON OPERATIONAL REQUIREMENTS

Aside from constraints placed on land treatment system design by the regulatory agency, the effects and need for preapplication treatment on the various land treatment systems is important.

Slow-Rate Systems

In terms of preapplication treatment for the 18 slow-rate systems visited, the following was determined:

1. One system is preceded by primary treatment.

2. Seven systems are preceded by intermediate-level treatment.

3. One system is preceded by an intermediate level of pretreatment followed by disinfection.

4. Three facilities are preceded by secondary treatment.

5. Four facilities are preceded by secondary treatment with disinfection.

6. Two facilities are preceded by tertiary treatment with disinfection.

Therefore, a wide range of possible preapplication treatment levels prior to land application were visited. Putting aside any secondary reasons, such as costs, labor requirements, or regulation, there does not appear to be sufficient reason to discount any degree of preapplication treatment equal to or greater than primary prior to a slow-rate system, as the system at Fontana operates acceptably. This is not to say, however, that higher degrees of preapplication treatment are not warranted. The degree of preapplication treatment should be decided upon based on factors such as the potential for disease transmission through the crop grown, or through direct contact of individuals with the wastewater. In addition, the aesthetics must be considered, including visual aesthetics and odor potential. For example, landscape irrigation with primary effluent should not be utilized due to the aesthetic nuisances (visual and odor) and the potential for public health problems.

Rapid Infiltration Systems

Of the wastewater applied at the seven rapid infiltration sites, three were pretreated to a primary level; one was pretreated to an intermediate level; one was pretreated to a secondary level; one was pretreated to a secondary level with disinfection; and one was pretreated to a tertiary degree with disinfection. Excluding the costs associated with these various options, there is no technical reason why a rapid infiltration system, preceded by any level of preapplication treatment equal to or greater than primary, should not be functional.

This is not to say, however, that the potential for problems such as groundwater pollution does not exist. This problem was noted in the case of facility 023 (Landis Sewage Authority, Vineland, New Jersey), where the rapid infiltration system will be replaced by a slow-rate system preceded by secondary treatment in the near future. From merely an operation and maintenance point of view, however, a minimum level of primary treatment prior to the rapid infiltration system is acceptable, with the understanding that the amount of bed maintenance will decrease as the degree of preapplication treatment increases.

Overland Flow Systems

At facility 018 (Easley, South Carolina) both overland flow preceded by preliminary treatment and oxidation pond treatment (intermediate level) were practiced. Considering the dual nature of the Easley facility, two facilities were visited where the degree of preapplication treatment was preliminary; one facility was visited where the degree of preapplication treatment was intermediate prior to the overland flow system; one facility was visited where the degree of preapplication treatment was intermediate with disinfection; and one facility was visited where the degree of preapplication treatment was intermediate followed by disinfection.

Based on these different combinations, it appears that an overland flow treatment system can be functional if it is preceded by a minimum of preliminary preapplication treatment. In fact, at the Easley facility, it was found that the wastewater quality in terms of effluent suspended solids was indeed better when preliminary preapplication treatment preceded the overland flow system, as compared to when the intermediate (oxidation pond) effluent was applied to the overland flow site. Further discussion and presentation of the data is presented in Appendix A.

Two sites were visited which applied an intermediate level of pretreated wastewater; in one case the wastewater was disinfected prior to application, and, in the other case, disinfected following overland flow treatment. In both cases, the facility operation appeared to be successful. Based on the fact that the chlorine demand is a function of the wastewater BOD and ammonia levels, there would appear to be benefits to post chlorination. However, if there is a chance for pathogen regrowth during overland flow treatment, preapplication chlorination could solve the problem. Conversely, the disadvantage is that during storm events a large volume of wastewater would have to be chlorinated. From an operational viewpoint, both methods are acceptable.

SECTION 7

LAND TREATMENT OPERATION AND MAINTENANCE COSTS

LAND TREATMENT OPERATION AND MAINTENANCE COSTS -- A LITERATURE REVIEW

Two major sources which present the cost of wastewater treatment by land application are available. The first report, entitled "Costs of Wastewater Treatment by Land Application," EPA-430/9-75-003, was published in June 1975 and revised in September 1979. This document presents cost information for both the preliminary screening portion of a study and the detailed cost estimate portion. Cost is divided into categories which include land, preapplication treatment, transmission, storage, land application and recovery of renovated water. Curves are presented for capital costs, amortized capital costs, and operation and maintenance costs for flow rates ranging from 0.0044 to 4.38 m^3/s (0.10 to 100 mgd). The base for the costs given in the report is February 1973 dollars.

Data from "Costs of Wastewater Treatment by Land Application" were not used as the costs are specific to equipment and process units. Therefore, system costs for a typical facility are not readily available from the report.

In order to compare the field cost data collected to typical costs, it was decided that the cost should be compared to "average" costs, owing to the wide range of equipment in use. Therefore, data taken from the document "Water Reuse and Recycling," Evaluation of Treatment Technology, volume 2, OWRT/RU-79/2, were used. The document presents capital and amortized capital cost data, along with operation and maintenance costs for land treatment systems at three different levels, i.e., favorable, moderate, and unfavorable conditions.

The conditions used for determining whether or not a system is favorable, moderate, or unfavorable include factors such as:

1. Degree of preapplication treatment.

2. Storage.

3. Transportation distance.

4. Pumping head.

5. Underdrain spacing.

6. Type of wastewater application equipment.

These factors and their values are presented in Table 20.

In order to determine average costs, a moderately-favorable condition for the slow-rate system, the rapid infiltration system, and the overland flow system was chosen as it was decided that the moderately-favorable condition most closely reflected the average conditions found during the survey.

All costs were taken from Appendix C of "Water Reuse and Recycling." In Appendix C, the data are presented on a system-by-system basis for the various components making up the system for treatment plant sizes of 0.044 m^3/s (1.0 mgd), 0.438 m^3/s (10 mgd), and 2.19 m^3/s (50 mgd).

All costs presented in the OWRT report were updated to the second quarter of 1980, utilizing the EPA cost indices. The escalation factors utilized were from the EPA Operation and Maintenance Cost Index as presented in the "Innovative and Alternative Technology Assessment Manual," EPA 430/9-78-009 (EPA, 1980). The indices were further extended to the second quarter of 1980 utilizing data from Michel (1980).

Appendix C of "Water Reuse and Recycling" presents 12 processes which are cost components of the slow-rate irrigation system. Some of these components, however, included preapplication treatment processes, and were therefore not included in the analysis. The processes which are included in the cost data include:

1. Force mains.

2. Monitoring wells.

3. Storage.

4. Distribution pumping.

5. Center pivot spray.

TABLE 20. RANGE OF CONDITIONS FOR LAND TREATMENT SYSTEMS[1]

	Slow-Rate			Rapid Infiltration			Overland Flow		
Parameter	**Favorable**	**Moderate**	**Unfavorable**	**Favorable**	**Moderate**	**Unfavorable**	**Favorable**	**Moderate**	**Unfavorable**
Preapplication Treatment	Aerated pond, 3-day detention, chlorine dosage = 5 mg/L			Aerated pond, 3-day detention, chlorine dose = 5 mg/L			Aerated pond, 3-day detention		
Storage	4 months, unlined	6 months, unlined	7 months, lined	20 days, unlined	20 days, unlined	20 days, lined	4 months, unlined	6 months, unlined	7 months, lined
Transport Distance[2]									
0.044 m^3/s	305 m	610 m	1,220 m	305 m	610 m	1,220 m	305 m	610 m	1,220 m
0.438 m^3/s	305 m	610 m	3,050 m	305 m	610 m	3,050 m	305 m	610 m	3,050 m
2.19 m^3/s	305 m	1,830 m	9,140 m	305 m	1,830 m	9,140 m	305 m	1,830 m	9,140 m
Pumping Head[3] m	15.2	45.7	91.4	7.6	22.9	45.7	7.6	22.0	45.7
Application Method	Center pivot	Center pivot	Center pivot	--	--	--	--	--	--
Irrigated Area[4] ha/1,000 m^3/day[3]	10.7	26.7	53.5	--	--	--	4.3	7.5	21.4
Basin Area-- ha/1,000 m^3/day	--	--	--	0.21	1.2	10.7	--	--	--
Total Area-- ha/1,000 m^3/day	13.9	34.7	69.5	0.28	1.4	13.9	5.6	9.7	27.8
Crop Revenue[5] net $/ha	40	10	4	--	--	--	--	--	--
Underdrain Spacing	None	122 m	30.5 m	--	--	--	--	--	--
Recovery Wells	--	--	--	30.5 m depth, 90% recovery			--	--	--
Runoff Collection	--	--	--	--	--	--	Open ditches, 80% recovery, chlorination, 5 mg/L		

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[1] Data adapted from OWRT/RU-79/2

[2] m^3/s x 22.8245

[3] m x 3.281 = ft

[4] ha/1,000 m^3/day x 9.355 = acre/mgd

[5] $/ha x 2.471 = $/acre

Capital costs and amortized capital costs were not included. The three operational costs include electrical costs, maintenance material costs, and labor costs. Table 16 presents the cost data in second quarter 1980 dollars for the slow-rate system.

The same approach was taken for the rapid infiltration system and the operational costs are shown in Table 17. Components which were included are:

1. Distribution pumping.
2. Monitoring wells.
3. Force mains.
4. Infiltration basins.

A similar process was used to calculate the overland flow operational costs, and they are presented in Table 18. The overland flow costs include:

1. Force mains.
2. Distribution piping.
3. Monitoring wells.
4. Distribution.
5. Runoff collection.
6. Chlorination of discharge.
7. Storage.

The cost data for the slow rate, rapid infiltration, and overland flow treatment systems are plotted in Figures 6 through 8. The data are plotted on a log plot which gives a linear relationship for values below and above the maximum and minimum design flows. The curves have been extrapolated in order to allow comparison with the lower flow facilities visited during this study.

LAND TREATMENT OPERATION AND MAINTENANCE COSTS -- SITE SURVEY

During the site visits, data were collected on the cost of preapplication treatment and land treatment systems. Difficulties were encountered during the collection of these data because municipalities often keep total operating budgets which

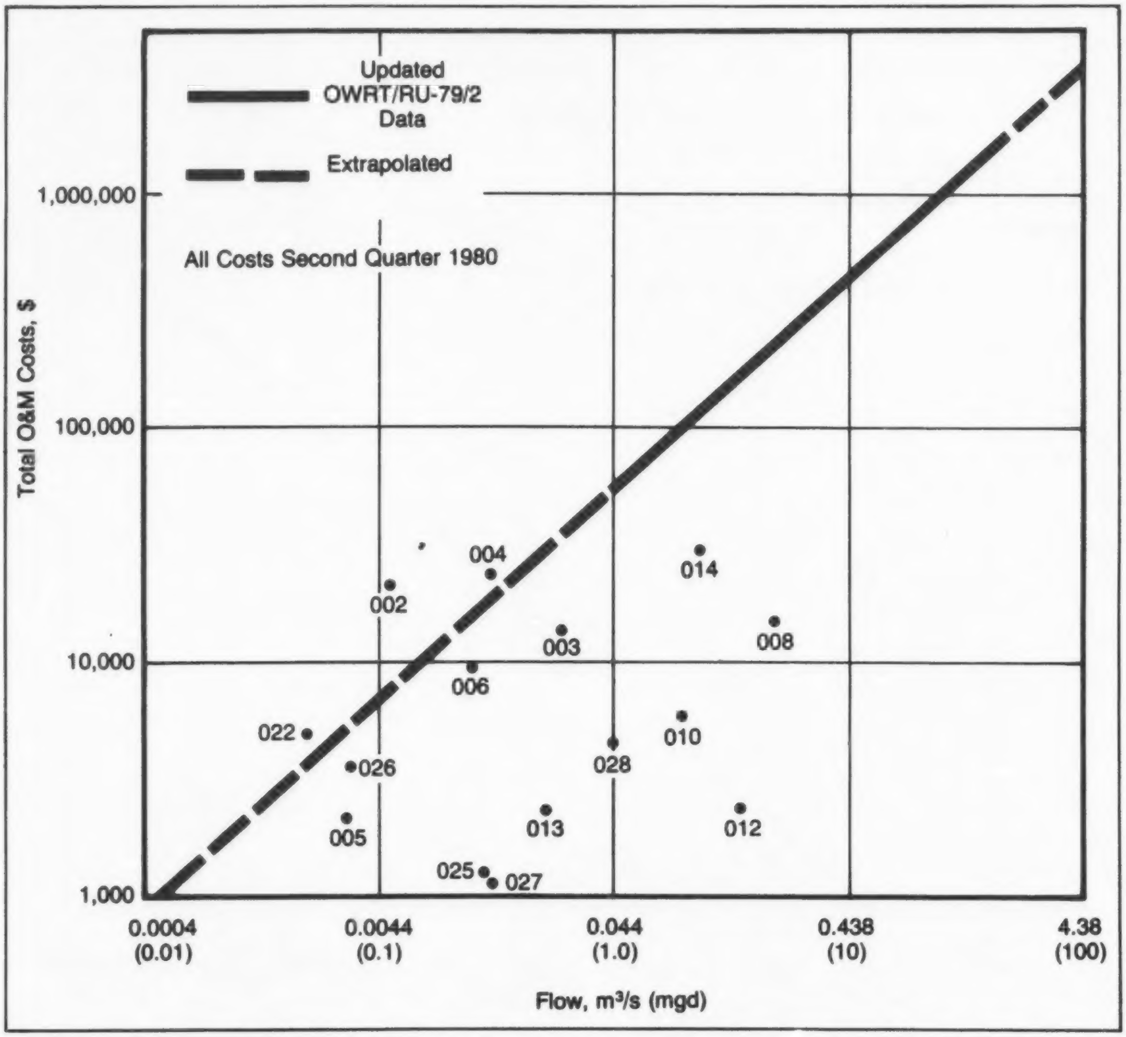

Figure 6. Slow-rate land treatment operation and maintenance costs.

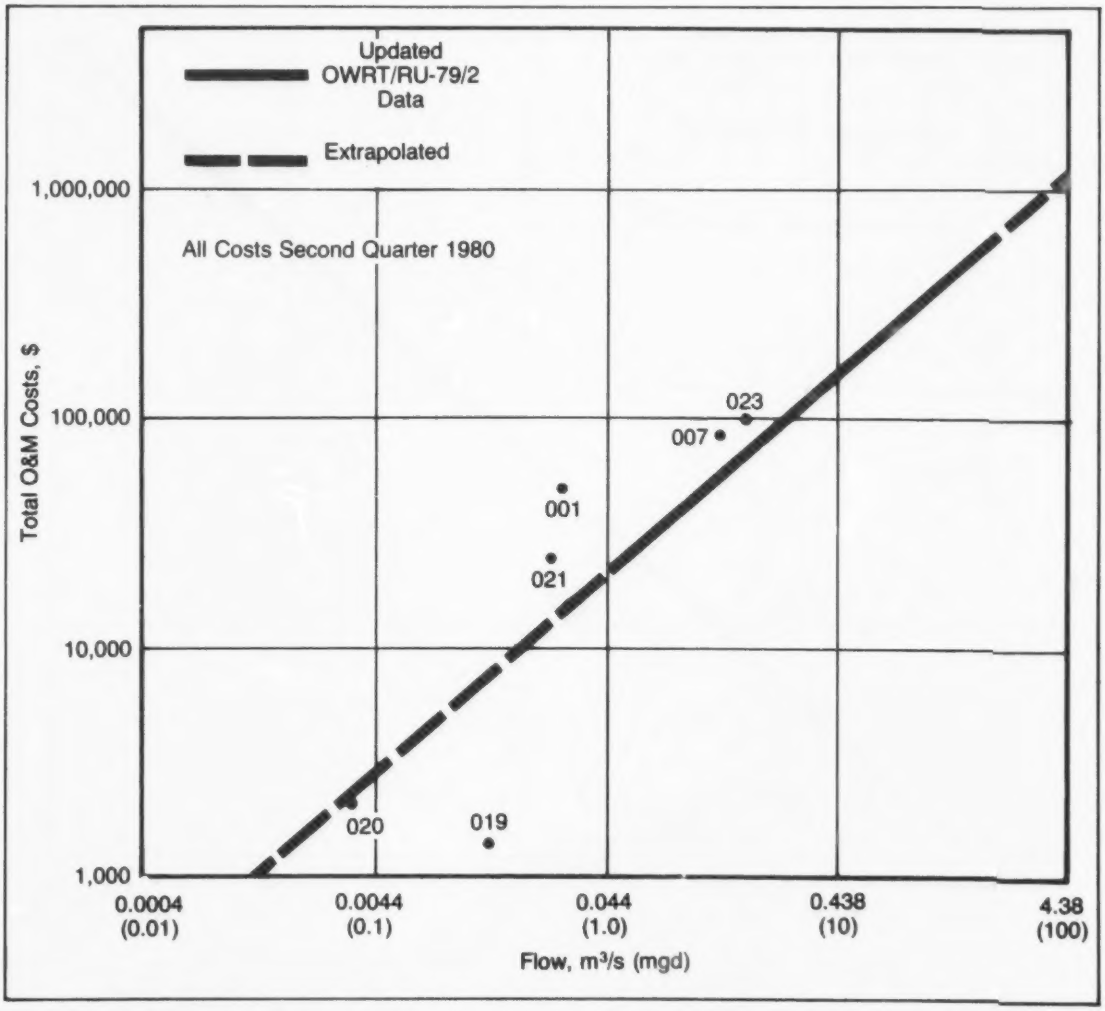

Figure 7. Rapid infiltration land treatment operation and maintenance costs.

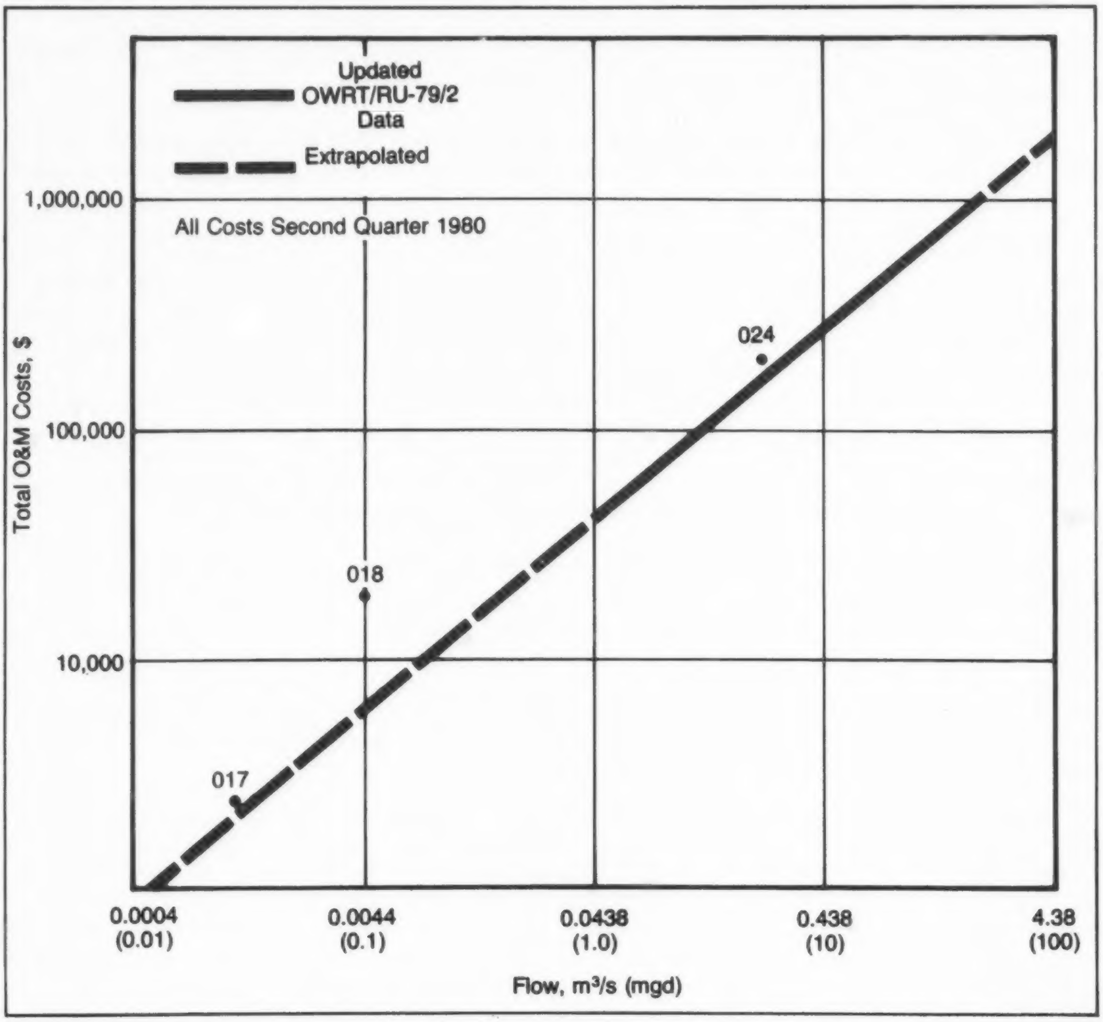

Figure 8. Overland flow land treatment operation and maintenance costs.

cover both wastewater treatment and wastewater collection. Therefore, for these facilities, the cost of collection had to first be separated from the entire budget. Additionally, plants typically do not keep separate budgets for the land treatment portion as opposed to the preapplication treatment portion, and these numbers had to be worked out during the site survey. Following conclusion of the on-site survey, numbers were checked and compared with energy and manpower usage. Facilities personnel were called back to eliminate discrepancies.

As the various authorities and municipalities kept records for different periods, the first task was to update the costs to second quarter 1980 to make them compatible with the updated costs from the literature. Once again this was done utilizing the EPA Operations and Maintenance Costs Index, as discussed previously. In addition, the budget information collected consisted of approximately 10 different categories in which the operation and maintenance costs were divided. In order to compare the costs from the field survey to the costs reported in the literature, these 10 categories had to be divided into the three categories of electrical consumption costs, maintenance material costs, and labor costs. As there were additional costs which did not fit into any one of these three categories, a fourth cost, i.e., a miscellaneous cost figure, was included.

Table 21 shows the data developed, based on this effort. The table includes the cost of operation and maintenance at the land treatment sites visited, and divides the cost into labor, power, maintenance materials, miscellaneous, and total O&M, where possible. In addition, the total land application O&M costs were also plotted on Figures 6, 7, and 8 in an attempt to show how the actual operation and maintenance costs compared to reported (literature) operation and maintenance costs.

Before reaching any conclusions, it should be remembered that the data in these figures are based on a specific set of conditions. In addition, the operation and maintenance costs of the various facilities are presented without regard to the numerous possible operating strategies. With this in mind, conclusions can be reached. For example, in Figure 6 it is noted that of the 15 sites shown on the list, costs for only three sites, facilities 002, 004, and 022 appear higher, and therefore, more expensive than the reported literature costs. In terms of operations, these three facilities are all run by the wastewater treatment plant staff, and therefore, incur substantial labor requirements. In fact, the other three facilities which are run by the wastewater treatment agency (003, 005, and 006) are in general agreement with the reported O&M costs from the literature. By comparison, plants such as facilities 025 and 027,

TABLE 21. LAND APPLICATION O&M COST BREAKDOWN

				Land Application O&M Costs, $[1]				
Facility Name	Site No.	Flow Rate[2] (m^3/s)	Type of Land Treatment[3]	Labor	Power	Maintenance Materials	Miscellaneous	Total
Village of Lake George WWTP	001	0.0280	RI	43,440	2,908	1,864	3,859	52,071
North Branch Fire District No. 1 WPCF	002	0.0049	SR	12,569	3,041	1,100	4,476	21,186
City of Hart WWTF	003	0.0267	SR	4,098	9,387	---	---	13,485
City of Fremont WWTP	004	0.0133	SR	10,004	3,031	9,816	523	23,374
Village of Ravenna STP	005	0.0032	SR	315	---	805	1,084	2,204
City of Wayland WWTP	006	0.0110	SR	2,426	2,266	4,187	576	9,455
Fontana Regional Plant No. 3	007	0.1266	RI,SR	43,473	9,480	24,812	8,234	85,999
Pomona Water Reclamation Plant	008	0.3505	SR[4]	3,153	12,116	---	---	15,269
Whittier Narrows Water Reclamation Plant	009	0.7010	RI	---	---	---	---	0
Palmdale Water Reclamation Plant	010	0.0811	SR	4,599	---	1,342	---	5,941
Irvine Ranch Water District	011	0.3505	SR	Not available	Not available	Not available	Not available	Not available
City of Tulare WPCF	012	0.1490	SR	2,404	---	---	---	2,404
City of Kerman WWTP	013	0.0228	SR	1,169	119	---	1,153	2,441
City of Manteca WWQCF	014	0.1008	SR	15,687	9,413	---	4,997	30,097
El Dorado Hills WWTP	015	0.0197	SR	Not available	Not available	Not available	Not available	Not available
U.S. Army COE, WES Overland Flow Site	016	0.0009	OF	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Falkner WWTF	017	0.0012	OF	1,750	121	526	---	2,397
Easley Combined Utilities System Overland Flow Project	018	0.0044	OF	14,944	2,200	6,075	5,440	28,659
Town of Wareham WPCF	019	0.0140	RI	1,386	---	---	---	1,386
Chatham WPCF	020	0.0035	RI	2,124	---	---	---	2,124
Town of Barnstable WPCF	021	0.0252	RI	13,660	---	11,512	---	25,172
Kendal/Crosslands Lagoon System	022	0.0022	SR	1,229	2,810	1,002	---	5,041
Landis Sewage Authority	023	0.1753	RI	52,600	12,500	20,000	15,000	101,000
Campbell Soup (Texas), Inc.	024	0.2234[5]	OF	125,118	Not available	79,931	9,139	214,188
City of Coleman WWTP	025	0.0175	SR	1,268	---	---	---	1,268
City of Santa Anna WWTP	026	0.0033	SR	2,590	70	400	---	3,060
City of Winters WWTP	027	0.0131	SR	---	1,129	---	---	1,129
City of Sweetwater WPCP	028	0.0438	SR	2,026	1,624	960	---	4,610

---

[1] Second quarter 1980 costs.

[2] $m^3/s \times 22.8245$ = mgd

[3] SR = Slow rate
RI = Rapid infiltration
OF = Overland flow

[4] Potential for RI exists.

[5] Five-day average production flow. Yearly average flow = 0.1796 m^3/s.

Key

WWTP	- Wastewater treatment plant
WPCF	- Water pollution control facility
WWTF	- Wastewater treatment facility
STP	- Sewage treatment plant
WWQCF	- Wastewater quality control facility
WPCP	- Water pollution control plant

which are the two least expensive plants, irrigate either in conjunction with a farmer (facility 025), or the irrigation is carried out entirely by the farmer (facility 027). In fact, with the possible exception of facility 026, the facilities operated either jointly with or independent of the wastewater agency represent a data set parallel and to the right of the OWRT/RU-79/2 data. Therefore, for a slow-rate land treatment system, it would appear that the operation and maintenance costs are directly related to the method by which the system is operated. By contractually having an arrangement with a farmer who irrigates and manages the farm, the labor required of the treatment plant operators is minimized. In addition, the benefit of receiving money for the sale of the reclaimed water exists.

In Figure 7 the rapid infiltration land treatment operation and maintenance costs gathered are compared to the reported costs, and it is noted that four of the plants report costs higher and two of the plants report costs lower than the literature values. When utilizing the graphs, it should be remembered that the scale is log-log, therefore, a deviation from the line represents a substantial difference in cost. Even so, only two facilities, 001 and 019, differ greatly from the reported costs. In the case of facility 001, this high cost could be related to the apparent excess of labor which was noted during the plant visit. Conversely, at facility 019 a minimum of labor was required for infiltration of the effluent water, and there were minimal costs associated with the system. One important additional factor is that the OWRT labor costs are based on a preapplication treatment level of a two-stage aerated lagoon system, and therefore, the labor required for bed maintenance varies greatly from some of the sites visited.

Figure 8 presents the overland flow land treatment operation and maintenance costs as a function of flow. Only four sites were visited. One site had no cost information and one site, facility 024, treated industrial wastewater. It would be unrealistic, therefore, to draw any conclusions from the graph. It is noted, however, that facility 017 is fairly close to the extrapolated reported value, and that facility 018 is a combined treatment and research facility; therefore, its costs do not necessarily reflect actual operation costs at a normal facility.

Based only on the limitations of the data gathering study and the differences in the preapplication plants, Table 22 presents the preapplication and land application treatment operation and maintenance costs as a function of dollars per cubic meter of wastewater flow. The least expensive preapplication treatment costs $0.011 per cubic meter at facility 027 (Winters, Texas), at which the preapplication treatment consisted of an

TABLE 22. PREAPPLICATION AND LAND APPLICATION TREATMENT O&M UNIT COSTS

Facility Name	Site No.	Flow Rate[1] (m^3/s)	Type of Land Treatment System	Degree Preapplication Treatment	Preapplication Treatment O&M Costs,[2] $\$/m^3$	Land Treatment O&M Cost, $\$/m^3$	Total Treatment O&M Cost, $\$/m^3$
Village of Lake George WWTP	001	0.0280	RI	Intermediate	0.083	0.059	0.142
North Branch Fire District No. 1 WPCF	002	0.0049	SR	Secondary with disinfection	0.298	0.136	0.434
City of Hart WWTF	003	0.0267	SR	Intermediate	0.082	0.016	0.098
City of Fremont WWTP	004	0.0133	SR	Secondary with disinfection	0.075	0.056	0.131
Village of Ravenna STP	005	0.0032	SR	Intermediate	0.129	0.022	0.151
City of Wayland WWTP	006	0.0110	SR	Intermediate with disinfection	0.068	0.027	0.095
Fontana Regional Plant No. 3	007	0.1266	RI,SR	Primary	0.027	0.022	0.049
Pomona Water Reclamation Plant	008	0.3505	SR[4]	Tertiary with disinfection	0.061[3]	0.002	0.063
Whittier Narrows Water Reclamation Plant	009	0.7010	RI	Tertiary with disinfection	0.030[3]	-----	0.030
Palmdale Water Reclamation Plant	010	0.0811	SR	Intermediate	0.045	0.002	0.047
Irvine Ranch Water District	011	0.3505	SR	Tertiary with disinfection	0.181	Not available	-----
City of Tulare WPCF	012	0.1490	SR	Intermediate	0.170	0.0005	0.170
City of Kerman WWTP	013	0.0228	SR	Secondary	0.173	0.003	0.176
City of Manteca WWQCF	014	0.1008	SR	Intermediate	0.101	0.009	0.110
El Dorado Hills WWTP	015	0.0197	SR	Secondary with disinfection	Not available	Not available	-----
U.S. Army COE, WES Overland Flow Site	016	0.0009	OF	Intermediate	Not available	Not available	-----
Falkner WWTF	017	0.0012	OF	Intermediate with disinfection	0.059	0.062	0.121
Easley Combined Utilities System Overland Flow Project	018	0.0044	OF	Preliminary and intermediate followed by disinfection	-----	0.207	0.207[5]
Town of Wareham WPCF	019	0.0140	RI	Secondary with disinfection	0.266	0.003	0.269
Chatham WPCF	020	0.0035	RI	Secondary	0.725	0.019	0.744
Town of Barnstable WPCF	021	0.0252	RI	Primary	0.114	0.032	0.146
Kendal/Crosslands Lagoon System	022	0.0022	SR	Secondary with disinfection	0.199	0.073	0.272
Landis Sewage Authority	023	0.1753	RI	Primary	0.042	0.018	0.060
Campbell Soup (Texas), Inc.	024	0.2234[6]	OF	Preliminary	-----	0.038[7]	0.038
City of Coleman WWTP	025	0.0175	SR	Secondary with disinfection[8]	0.077	0.003	0.080
City of Santa Anna WWTP	026	0.0033	SR	Intermediate	0.025	0.029	0.055
City of Winters WWTP	027	0.0131	SR	Intermediate	0.011	0.003	0.014
City of Sweetwater WPCP	028	0.0438	SR	Secondary	0.052	0.003	0.055

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[1] $m^3/s \times 22.8245$ = mgd
[2] $\$/m^3 \times 3.7854$ = \$/1,000 gallons.
[3] Does not include sludge treatment and disposal costs.
[4] Provisions for RI exist.
[5] Does not include oxidation pond preapplication treatment costs.
[6] Five-day average production flow. Yearly average flow = 0.1796, and costs are based on yearly average flow.
[7] Does not include electrical consumption.
[8] Disinfection of surface discharge only.

Key

WWTP	Wastewater treatment plant
WPCF	Water pollution control facility
WWTF	Wastewater treatment facility
STP	Sewage treatment plant
WWQCF	Wastewater quality control facility
WPCP	Water pollution control plant

Imhoff tank followed by oxidation/holding ponds. The most expensive preapplication treatment operation and maintenance cost occurred at facility 020 (Chatham, Massachusetts), and was $0.725 per cubic meter. Preapplication treatment at this facility consists of an activated sludge system. The least expensive land treatment system was facility 012 (City of Tulare, California) where the operation and maintenance cost was $0.0005 per cubic meter. This facility utilized a slow-rate system where the fields were irrigated by both ridge and furrow and border strip irrigation. All water flowed by gravity, and all irrigation was carried out by a farmer, therefore, the costs incurred by the City were low.

The most expensive land treatment system was facility 018 (Easley, South Carolina Combined Utilities System Overland Flow Project) where the operation and maintenance cost was $0.207 per cubic meter. It is not necessarily accurate to say that this is the most expensive project, however, as this plant is a combined operating plant and research project. Aside from this facility, the second most expensive land treatment system in terms of operation and maintenance is facility 002 (North Branch Fire District No. 1, Dover, Vermont) where the operation and maintenance cost was $0.136 per cubic meter. At this facility secondary effluent is chlorinated and sprayed on a woodland site.

Due to complications involved in differentiating between preapplication treatment and land treatment operation and maintenance costs, the most valid column in Table 22 is the final column where the total treatment operation and maintenance costs are calculated. Based on these data, facility 012 (City of Winters, Texas) currently offers the least costly wastewater treatment facilities as the combined cost is only $0.014 per cubic meter. The most expensive treatment operation is facility 020 (Chatham, Massachusetts) where the total treatment operation and maintenance cost was $0.744 per cubic meter. A 50 times difference in the operation and maintenance costs is seen by comparing the costs at these two facilities.

One final note about Table 22 regards facilities 008 and 009 which are operated by the Los Angeles County Sanitation District. Although both of these plants provide tertiary wastewater treatment, the preapplication treatment operation and maintenance costs are reasonably low. These costs are low because there is no on-site sludge treatment or disposal at either facility, and sludge treatment costs are not back charged to the generating facility. In addition, the facilities typically do not treat their sidestreams further, causing the costs to be lower than the actual cost of treatment.

A commonly posed question is "What is the effect of the degree of preapplication treatment on the cost of the operation and maintenance of the subsequent land treatment facilities?" For example, does the addition of a secondary treatment facility as opposed to a primary treatment facility reduce the operation and maintenance costs of a rapid infiltration system. To assess the situation, Table 23 was prepared. The degree of preapplication treatment is divided into numerous categories. Preliminary treatment consists of screening, grit removal, and comminution. Primary treatment consists of primary sedimentation. Intermediate treatment is defined as that degree of treatment which is an additional process past primary treatment but does not meet the requirements for secondary treatment. Secondary treatment is defined as a process able to meet 30 mg/L BOD_5 and suspended solids on a yearly average. Tertiary treatment is defined as any plant which has additional treatment after secondary treatment. All levels of preapplication treatment may or may not include a disinfection process.

Due to the modicum of data, little can be said about overland flow operation and maintenance costs as a function of preapplication treatment, and conclusions will only be discussed for slow-rate and rapid infiltration systems. As can be seen in Table 23, total operation and maintenance cost data were available at 16 of the 18 slow-rate land treatment systems visited.

The preapplication treatment systems at these 16 sites consisted of the following:

1. Seven plants with intermediate treatment.
2. One plant with intermediate treatment and disinfection.
3. Two plants with secondary treatment.
4. Four plants with secondary treatment followed by disinfection.
5. Two plants with tertiary treatment followed by disinfection.

The average operation and maintenance costs for preapplication treatment, land application treatment, and the total costs were calculated as a function of degree of preapplication treatment. Calculating these averages and then arranging them in order of increasing costs, the preapplication treatment costs

TABLE 23. O&M UNIT COSTS AS A FUNCTION OF DEGREE OF PREAPPLICATION TREATMENT AND LAND TREATMENT SYSTEM TYPE

Degree of Preapplication Treatment	Type of Land Treatment System[1]	Site No.	Flow Rate[2] (m^3/s)	Preapplication Treatment O&M Costs,[3] $/$m^3$	Land Treatment O&M Costs, $/$m^3$	Total Treatment O&M Costs, $/$m^3$
Preliminary	OF	024	0.2234[4]	-----	0.038[5]	0.038
Primary	RI	021	0.0252	0.114	0.032	0.146
		007[6]	0.1266	0.027	0.022	0.049
		023	0.1753	0.042	0.018	0.060
Intermediate	SR	005	0.0032	0.129	0.022	0.151
		026	0.0033	0.025	0.029	0.055
		027	0.0131	0.011	0.003	0.014
		003	0.0267	0.082	0.016	0.098
		010	0.0811	0.045	0.002	0.047
		014	0.1008	0.101	0.009	0.110
		012	0.1490	0.170	0.0005	0.170
	RI	001	0.0280	0.083	0.059	0.142
Intermediate with disinfection	SR	006	0.0110	0.068	0.027	0.095
	OF	017	0.0012	0.059	0.062	0.121
		018[7]	0.0044	-----	0.207	0.207[8]
Secondary	SR	013	0.0228	0.173	0.003	0.176
		028	0.0438	0.052	0.003	0.055
	RI	020	0.0035	0.725	0.019	0.744
Secondary with disinfection	SR	022	0.0022	0.199	0.073	0.272
		002	0.0049	0.298	0.136	0.434
		004	0.0133	0.075	0.056	0.131
		025[9]	0.0175	0.077	0.003	0.080
	RI	019	0.0140	0.266	0.003	0.269
Tertiary with disinfection	SR	008	0.3505	0.061	0.002	0.063
		011	0.3505	0.181	Not available	-----
	RI	009	0.7010	0.030	0	0.030

---

[1] SR = Slow rate
RI = Rapid infiltration
OF = Overland flow

[2] $m^3/s \times 22.8245$ = mgd

[3] $/$m^3 \times 3.7854$ = $/1,000 gallons.

[4] Five-day average production flow. Yearly average flow = 0.1796 m^3/s.

[5] Does not include electrical usage.

[6] Costs representative of RI system, although SR is also possible.

[7] 25% of flow treated at site is screened raw wastewater.

[8] 75% of flow pretreated by oxidation pond. 25% of flow, comminution and screening only. Oxidation pond preapplication costs not included.

[9] Disinfection for surface discharge only.

for slow-rate systems would be as follows:

1. Intermediate treatment with disinfection.
2. Intermediate treatment.
3. Secondary treatment.
4. Secondary treatment with disinfection.

The slow-rate land application operation and maintenance costs, in increasing order by preapplication system, are:

1. Secondary treatment.
2. Intermediate treatment.
3. Intermediate treatment with disinfection.
4. Secondary treatment with disinfection.

In total slow-rate system operation and maintenance cost, the order in terms of increasing costs, by preapplication system, would be:

1. Intermediate treatment.
2. Intermediate treatment with disinfection.
3. Secondary treatment.
4. Secondary treatment with disinfection.

The total costs have the greatest level of confidence, and they show that the total cost increases as a function of degree of preapplication treatment. For this analysis, the tertiary plants were not included as the costs for facility 008 are artificially low due to sludge handling and disposal costs being excluded, and the fact that there are no costs for land treatment for facility 011.

A similar comparison can be made for the rapid infiltration system. However, in this case, fewer data exist as only seven sites were visited: three primary, one intermediate, one secondary, one secondary with disinfection, and one tertiary with disinfection. The tertiary facility with disinfection must be discounted, as facility 009 (Whittier Narrows Water Reclamation Plant) has a rapid infiltration system which is used in conjunction with groundwater recharge with the Los Angeles County Flood

Control District, and there are no costs associated with land application of wastewater as the water accounts for only approximately 13% of the total flow to the recharge area. Once again, the average preapplication treatment and land treatment costs for the rapid infiltration systems can be calculated. In terms of increasing costs, the preapplication systems are arranged as intermediate, secondary with disinfection, primary, and secondary. In terms of land application operation and maintenance costs, however, the order in terms of increasing costs is secondary with disinfection, secondary, intermediate, and primary, therefore reflecting the intuitive order with which the operation and maintenance costs should follow. In terms of total costs, the order is primary, intermediate, secondary with disinfection, and secondary. These costs are extremely biased, however, by the secondary facility 020 which had a very high preapplication treatment cost.

The next step in the analysis is to compare the cost of the slow-rate system with the rapid infiltration system for the same degree of preapplication treatment. Using the data collected, it is seen that the slow-rate systems were substantially less expensive on an operation and maintenance cost basis in terms of dollars per cubic meter of wastewater treated, regardless of the degree of preapplication treatment. This idea is contrary to the previously reported information such as that presented in Tables 16 and 17 where the slow-rate land treatment system operation and maintenance costs are more than 2.8 times as high as the rapid infiltration costs. Reflecting back to Figure 6, however, and the fact that the treatment costs were substantially lower than the reported treatment costs, this is not so surprising. Once again the major factor involved would appear to be the labor involved or not involved in the slow-rate system if the water is given or sold to a farmer.

A final note about the previous analysis is that the analysis is based on a small sample, i.e., a total of only seven rapid infiltration and 16 slow-rate systems. In addition, some systems are operating below design capacity and some are operating substantially above design capacity, further confusing the analysis. Given all the limitations of the data, however, it still appears that the rapid infiltration system is more expensive to operate than the slow-rate system. This is more than likely due to the labor requirements of the rapid infiltration system which must be borne by the treatment authority running the system, whereas slow-rate system operations can be carried out by private individuals (farmers), and the authority will not incur the cost.

SECTION 8

RECOMMENDED OPERATION AND MAINTENANCE PRACTICES

INTRODUCTION

This section presents the recommended operation and maintenance practices for the three types of land treatment systems based on information collected during the site visits and subsequent data analysis.

SLOW-RATE SYSTEMS

A person with a farming background should either operate the land treatment system or assist in its operation to allow farming decisions based on experience.

The operation of a slow-rate land treatment system is basically fixed by the design of the system. Therefore, the operation tends to be fairly straightforward and only three operational parameters can be varied. These parameters are:

1. Amount of wastewater to be applied per application.

2. Frequency of application.

3. Which field should be irrigated.

The product of these three decisions must be the equivalent of the total amount of wastewater which must be applied annually (or in a growing season). This is the method by which most facilities are currently being operated. During winter operations, however, some facilities occasionally flood fields to maximize the wastewater disposal option.

Maintenance requirements for a slow-rate land treatment system are straightforward and should not cause the maintenance staff/operators any particular problems. A routine maintenance schedule is suggested.

RAPID INFILTRATION SYSTEMS

The operation of a rapid infiltration land treatment system is fairly simple as it consists basically of bed rotation.

Bed rotation is typically based on visual estimates as to which bed is ready to receive the flow, and usually follows some sort of schedule. It is believed that many of the operational strategies discussed in the Process Design Manual (EPA, 1977) for increasing denitrification losses are simply not possible on an operating scale. The major reason behind this is that the denitrification losses are extremely difficult to measure in the laboratory, and, more than likely, impossible to measure in the field, particularly for smaller installations. In addition, the operator may not have the luxury of dosing an infiltration bed at the required schedule to maximize the denitrification as other considerations may make this schedule impossible.

The major consideration for operation of a rapid infiltration system is that the operators stay ahead of the beds in terms of bed maintenance, and continually insure that sufficient capacity exists to dispose of all of the influent wastewater. This is extremely important as the systems are usually designed without any facilities for wastewater storage. Once a facility gets in trouble, it may be difficult to correct the problem as wastewater must be applied to beds which may be flooded and therefore cannot be reworked; and the situation tends to go from bad to worse. Aside from infiltration bed maintenance, additional routine maintenance is required.

OVERLAND FLOW SYSTEMS

Unlike the other two land treatment systems, the overland flow system has the greatest potential for process control as the loading rate and the hours of application can be varied. In addition, various plots can be taken off-line to further increase the operational modifications the operator has at his disposal.

Operation of the overland flow system also requires knowledge of soil chemistry and biological processes that wastewater treatment personnel may not understand. Therefore, additional training is required. In addition, it is believed that following start-up, various combinations of hydraulic loading rates and application schedules should be investigated in order to optimize performance.

Aside from routine maintenance, an additional maintenance requirement, namely overland flow plot maintenance, exists. This consists of ensuring that a healthy cover crop is maintained and that any erosion problems are quickly corrected. These maintenance requirements may necessitate additional operator training.

SECTION 9

DESIGN DEFICIENCIES HINDERING OPERATIONS

INTRODUCTION

The purpose of this section is to point out existing deficiencies in the design of land treatment systems which were noted during the site survey. Preapplication treatment design deficiencies, if they could affect the subsequent land treatment facility, are also included.

In order to classify design deficiencies, six categories were designated:

1. Layout, arrangement, and placement of components.
2. Civil/structural considerations.
3. Hydraulic design considerations.
4. Mechanical design considerations.
5. Electrical/instrumentation design considerations.
6. Agronomic considerations.

PREAPPLICATION TREATMENT DESIGN DEFICIENCIES

The preapplication treatment design deficiencies are presented in Table 24. Basically, there was only one design deficiency which showed up at multiple plants, namely, that oxidation ponds were unprotected from the effects of erosion caused by wind-induced waves. At several plants, maintenance personnel were in the process of installing protection around the embankments at the water levels.

SLOW-RATE LAND TREATMENT DESIGN DEFICIENCIES

The design deficiencies noted at slow-rate systems are presented in Table 25.

TABLE 24. PREAPPLICATION TREATMENT DESIGN DEFICIENCIES[1]

Facility Name	Site No.	Layout, Arrangement, and Placement of Components	Civil/Structural Considerations	Hydraulic Design Considerations	Mechanical Design Considerations	Electrical/ Instrumentation Design Considerations	Agronomic Considerations
City of Fremont WWTP	004	None	Lack of oxidation pond embankment protection.	None	None	None	None
Village of Ravenna STP	005	None	Lack of oxidation pond embankment protection.	None	Need for staff gauges in oxidation ponds.	None	None
City of Wayland WWTP	006	None	Lack of oxidation pond embankment protection.	None	None	None	None
City of Tulare WPCF	012	None	Lack of oxidation pond embankment protection.	None	Inability to operate ponds in parallel or series operation. Inability to operate ponds at varying depths.	None	None
City of Kerman WWTP	013	None	Lack of oxidation pond embankment protection.	None	None	None	None
Falkner WWTP	017	None	Slopes on oxidation pond too steep for mowing.	None	Creosote lumber in chlorine contact tank causes "oil slick."	None	None
Easley Combined Utilities System Overland Flow Project	018	None	None	None	Raw sewage pump station subject to solids deposition and odor problems.	None	None
Town of Barnstable WPCF	021	None	None	None	Oil and grease from septage not sufficiently removed, thereby causing problems with rapid infiltration system.	None	None
Kendal/Crosslands Lagoon System	022	None	None	None	Maple tree "nibs" get into wet well and cause problems with distribution system.	None	None
City of Coleman WWTP	025	None	None	None	Effluent lift pumps as installed unable to pass solids and clog frequently. Recessed impellor pumps have solved problem.	None	None

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[1] Preapplication treatment deficiencies only as they impact land treatment systems.

TABLE 25. SLOW-RATE DESIGN DEFICIENCIES

Facility Name	Site No.	Layout, Arrangement, and Placement of Components	Civil/Structural Considerations	Hydraulic Design Considerations	Mechanical Design Considerations	Electrical/ Instrumentation Design Considerations	Agronomic Considerations
North Branch Fire District No. 1 WPCP	002	Allow greater clearance on each side of spray lines for access. Provide walking paths between lines to allow checking two lines at once.	Divert noncontaminated stormwater away from holding pond.	Spray lines should run up/downhill rather than follow contours to minimize low spots.	Improper spray nozzle for winter operation.	Provide communication between fields and control. room	None
City of Hart WWTP	003	None	None	Effect of addition hydraulic loading on water table should be studied.	Original pumps were unable to pass solids including leaves, grass, and vegetable solids.	None	Give specific recommendations on type of vegetation to be grown.
City of Fremont WWTP	004	None	None	Pumping required to both pretreatment facility and land treatment facility.	Valve arrangement does not allow for irrigation of individual cells within a field.	None	Topsoil removed prior to construction was never returned.
Village of Ravenna STP	005	None	Need for more uniform irrigation field grading. Higher berms surrounding irrigation field needed.	None	None	None	None
City of Wayland WWTP	006	None	Monitoring wells unable to supply adequate sample.	Water pumped to west fields, however, gravity flow is possible.	Center-pivot unit was steel, increasing "sinking in" problems.	None	Effect of soil type and texture not investigated prior to selection of irrigation equipment. Big gun irrigation system ties up tractor and is labor-intensive when moving is required.

TABLE 25. SLOW-RATE DESIGN DEFICIENCIES
(continued)

Facility Name	Site No.	Layout, Arrangement, and Placement of Components	Civil/Structural Considerations	Hydraulic Design Considerations	Mechanical Design Considerations	Electrical/Instrumentation Design Considerations	Agronomic Considerations
Palmdale Water Reclamation Plant	010	None	None	Insufficient water holding capacity.	None	None	None
City of Tulare WPCP	012	None	None	Insufficient water holding capacity.	None	None	None
City of Kerman WWTP	013	None	None	Pumps unable to supply sufficient water to distant fields.	None	None	None
City of Manteca WQCF	014	Provide better access to valves and structures utilized for wastewater distribution.	None	None	None	None	None
El Dorado Hills WWTP	015	None	None	Original pumps could not meet peak demand of golf course. Insufficient storage for seasonal demands.	Mosquito minnows and algae from ponds pumped to golf course clogging sprinklers.	None	None
Kendal/Crosslands Lagoon System	022	None	In-ground PVC valve boxes subject to frost heaving, allowing soil to fall in, requiring excavation.	None	None	None	None
City of Winters WWTP	027	Extremely poor layout causing a variety of operational problems.	None	None	None	None	None
City of Sweetwater WPCP	028	None	None	None	Line clogging (possibly due to oil and grease) would cause surge in lines, breaking unreinforced concrete pipe.	None	None

In terms of hydraulic design considerations, the major problem noted was that in some facilities pumping was required both to the headworks of the treatment facility and to the slow-rate land treatment system when the second pumping may not be necessary. A second hydraulic design consideration was that numerous plants had insufficient wastewater storage capacity to allow optimum facility operation.

The mechanical design considerations include improper nozzle selection, and pumps unable to pass solids to the land treatment system.

An agronomic consideration noted is the effect of soil type and texture on the selection of irrigation equipment. This problem was particularly acute in Wayland, Michigan where the center-pivot irrigation unit had made deep ruts in the field. This necessitated excavating and filling the ruts with washed gravel to allow subsequent operation of the unit.

RAPID INFILTRATION DESIGN DEFICIENCIES

The design deficiencies noted during the site visits to the rapid infiltration systems are presented in Table 26.

The major hydraulic design deficiency noted was that in several systems it was necessary to pump wastewater both to the pretreatment facility and subsequently to some or all of the rapid infiltration beds. This dual pumping is frequently an avoidable waste of energy.

OVERLAND FLOW DESIGN DEFICIENCIES

Of the four overland flow sites visited, two sites were research facilities, with the Army Corps of Engineers (Utica, Mississippi) facility being totally a research project, while the Easley, South Carolina facility was an operational research project in conjunction with Clemson University. With this in mind, the data in Table 27 indicate overland flow design deficiencies.

In terms of civil/structural considerations, the major problem concerned the tailwater collection ditches. These ditches, typically unlined, are difficult to maintain and are subject to erosion. Another civil/structural consideration is the effect of improper land grading during construction which manifests itself in ponding on the overland flow fields. A range of mechanical design deficiencies was noted during the plant visits. At

TABLE 26. RAPID INFILTRATION DESIGN DEFICIENCIES

Facility Name	Site No.	Layout, Arrangement, and Placement of Components	Civil/Structural Considerations	Hydraulic Design Considerations	Mechanical Design Considerations	Electrical/ Instrumentation Design Considerations	Agronomic Considerations
Village of Lake George WWTP	001	Insufficient width of berms between rapid infiltration beds to allow truck access and mowing.	None	Requirement to pump both to preapplication treatment and newer rapid infiltration beds.	None	None	None
Fontana Regional Plant No. 3	007	Flow diversion boxes interfere with vehicle access to various rapid infiltration beds.	Rapid infiltration bed embankments subject to erosion.	Certain rapid infiltration beds are less permeable than others; requires more subsurface exploration.	Float level controller in wet well "hangs up" on sludge accumulation.	None	None
Town of Wareham WPCF	019	None	None	Rapid infiltration bed underdrain system effluent pipes located below Agawam River high tide, making sampling impossible.	None	None	None
Chatham WPCF	020	None	Rapid infiltration beds should be fenced in.	None	None	None	None
Landis Sewage Authority	023	None	Rapid infiltration beds should be fenced in.	Requirement to pump to both preapplication treatment and newer rapid infiltration beds.	None	None	None

TABLE 27. OVERLAND FLOW DESIGN DEFICIENCIES

Facility Name	Site No.	Layout, Arrangement, and Placement of Components	Civil/Structural Considerations	Hydraulic Design Considerations	Mechanical Design Considerations	Electrical/ Instrumentation Design Considerations	Agronomic Considerations
U.S. Army COE, WES Overland Flow Site	016	None	None	None	Solenoid valve orifice too small and subject to plugging. Water meters used to measure plot runoff subject to plugging. Gutter distribution piping subject to plugging. Dual pumps from pond to plots are redundant and unnecessary.	None	None
Falconer WWTP	017	None	Off-site runoff should be diverted away from overland flow site. Better access and placement of tailwater collection and disposal channels required. More effective land grading to minimize ponding.	None	Effluent monitoring station too small to measure storm events. Dual pumps to spray overland flow plots are redundant and unnecessary.	None	None
Easley Combined Utilities System Overland Flow Project	018	None	Treated water collection ditches unlined, subject to erosion and difficult to mow since they remain wet.	None	Raw wastewater nozzles plugged. Valve pits filled with water, rusting and ruining solenoid valves. Chlorination equipment not flow proportional. Grass from fields is sucked into chlorine eductor system and clogs it. In-ground pipe is PVC, aboveground galvanized; when aboveground pipe is hit it breaks off at PVC/galvanized pipe joint.	In-ground electric lines to solenoid valves not placed in conduits.	Initial wastewater application prior to plots being fully seeded, causing erosion and subsequent poor wastewater distribution.
Campbell Soup (Texas), Inc.	026	None	Ponding of water on slopes.	None	Use PVC for all lines less than 0.15 m (6 in) as concrete and cast iron subject to breaking by soil movement due to wetting and drying cycles.	None	None

the Army Corps of Engineers site, there were problems with plugging of valves, meters, and piping. At the Easley, South Carolina overland flow site, there were mechanical problems including:

1. Raw wastewater nozzle plugging.
2. Valve pits filling up with water (which rusts the solenoid valves).
3. Grass being sucked up by chlorine eductor systems, with resultant clogging.
4. In-ground PVC pipe connected to above-ground galvanized pipe. When the above-ground pipe was hit, the PVC pipe would break underground, necessitating excavation.

One important agronomic deficiency was wastewater application prior to the plots being fully seeded. This happened at the Easley site, and caused substantial erosion and subsequent poor wastewater distribution. In addition, it was difficult to establish grass on the active site.

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APPENDIX A

TRIP REPORTS

Appendix A is a compendium of observations and data collected during the site survey portion of the study. The appendix is organized with a separate report for each of the sites.

In addition, location maps, process flow diagrams, and facility layouts are included for each report.

VILLAGE OF LAKE GEORGE WASTEWATER TREATMENT PLANT (# 001)

LAKE GEORGE, NEW YORK

RAPID INFILTRATION SYSTEM

GENERAL

Lake George, New York is located in the eastern portion of New York state, approximately 80 km (50 mi) north of Albany, in the Adirondack Mountains (Figure A-1). The area is a tourist attraction in both summer and winter due to the recreational value of Lake George. The treatment facility receives flow from both the Village of Lake George and the Town of Lake George; however, the facility is owned and operated by the Village. The facility was visited on March 24 and 25, 1980.

Lake George has a seasonal climate, and the yearly average temperature is 8.2°C (46.8°F). The yearly average precipitation is 0.95 m (37.3 in), whereas the estimated annual average Class A pan evaporation is 0.84 m (33 in).

The Village of Lake George wastewater treatment plant was designed to treat 0.077 m^3/s (1.75 mgd) to a secondary degree of treatment. Based on plant operating records, 0.028 m^3/s (0.64 mgd) of wastewater is currently being treated to an intermediate level, utilizing primary sedimentation followed by trickling filtration. Unchlorinated trickling filter effluent from the final settling tanks is then applied to the rapid infiltration beds. The treatment facilities primarily receive wastewater from the communities, and tourist support services. There are no major industrial discharges to the facility.

Both the preapplication treatment and the land application system have been on-line for 41 years, although expanded and upgraded various times. Regional wastewater treatment alternatives are currently being studied. However, there are no definite plans for the future of the facility. The land use in the vicinity of the Lake George facilities includes both residential and undeveloped areas.

PHYSICAL FACILITIES

All wastewater is pumped to the Village of Lake George Wastewater Treatment Plant through either the Town or Village

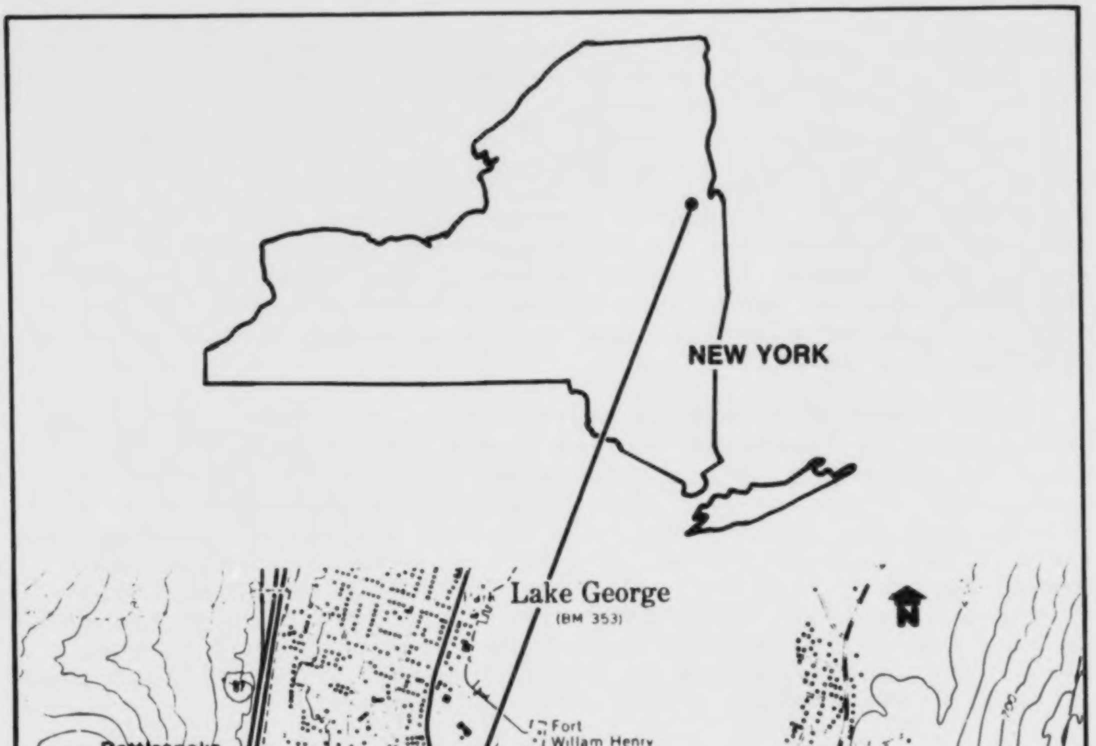

NEW YORK
Lake George
(BM 353)
N
Rattlesnake Cobble
Fort William Henry
Crosbyside
BEACH RD
EWELL ST
LAKE GEORGE
BATTLEFIELD PARK
LAKE GEORGE BEACH STATE PARK
Ruins
349
Preapplication and Land Treatment Area
Sewage Disposal
87
9
9L
9N
900
Tollgate
West Brook
Drive-in Theater
CANADA ST
Quarry
ROAD
POND
700
500
400
800
1100
600
INTERCHANGE 21
BM
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-1. Location map of Village of Lake George wastewater treatment plant (# 001), Lake George, New York.

force mains. There is no preliminary treatment at the facility, and following flow measurement, primary treatment is provided by either a circular Imhoff tank, or one of two circular clarigesters, all operating in parallel (Figure A-2). Biological treatment is accomplished in two high-rate rotating arm trickling filters, and one covered (wood slat) standard-rate fixed nozzle trickling filter. Secondary sedimentation facilities consist of two rectangular and two circular settling tanks. Excess biological sludge (humus) is pumped to one of the three clarigesters for stabilization (anaerobic digestion). During the warmer months, digested sludge is applied to sand drying beds prior to disposal in a landfill.

Unchlorinated trickling filter effluent from the final settling tanks is discharged to the rapid infiltration basins. There are 21 rapid infiltration beds -- 14 north beds and seven south beds (Figure A-3). The 14 north beds contain 1.4 ha (3.4 acres), and the seven south beds contain 0.81 ha (2.0 acres) for a total bed area of 2.2 ha (5.4 acres). When the plant commenced operation in 1939, only six north beds existed. Plant expansions in 1947, 1950, 1956, 1965, and 1970 brought the total to 21. Due to hydraulics, wastewater must be pumped to the south beds, utilizing one of two 3.7-kw (5 hp) centrifugal pumps rated at approximately 0.0063 m^3/s (100 gpm).

Although the south beds are larger and wastewater must be pumped to them, the wastewater distribution systems for both north and south beds are basically the same and consist of a centralized manhole with various slide gates. Wastewater is diverted from one bed to another by removing the slide gate and reinserting it in a different pipe. From the splitter manhole, wastewater then flows into the individual beds. In the newer south beds, concrete headwalls and splash plates are used to prevent erosion and distribute the water. In the older north beds, a clay pipe distributes the water onto rocks which are utilized for wastewater distribution and erosion control. Overflow pipes interconnect most of the beds. An approximately 0.9 to 1.5 m (3 to 5 ft) high earthen dike encloses the beds. The dikes are grassed, and constructed with one ramp per bed to allow equipment access.

The beds are constructed in an area consisting of natural delta sands whose depth reaches 28 m (92 ft), but is shallower in the south beds. The delta sands contain a small percent of coarse sand and gravel.

Aside from any storage inherent in the percolation beds themselves, there are no additional wastewater storage facilities. A total of 22 groundwater monitoring wells are located

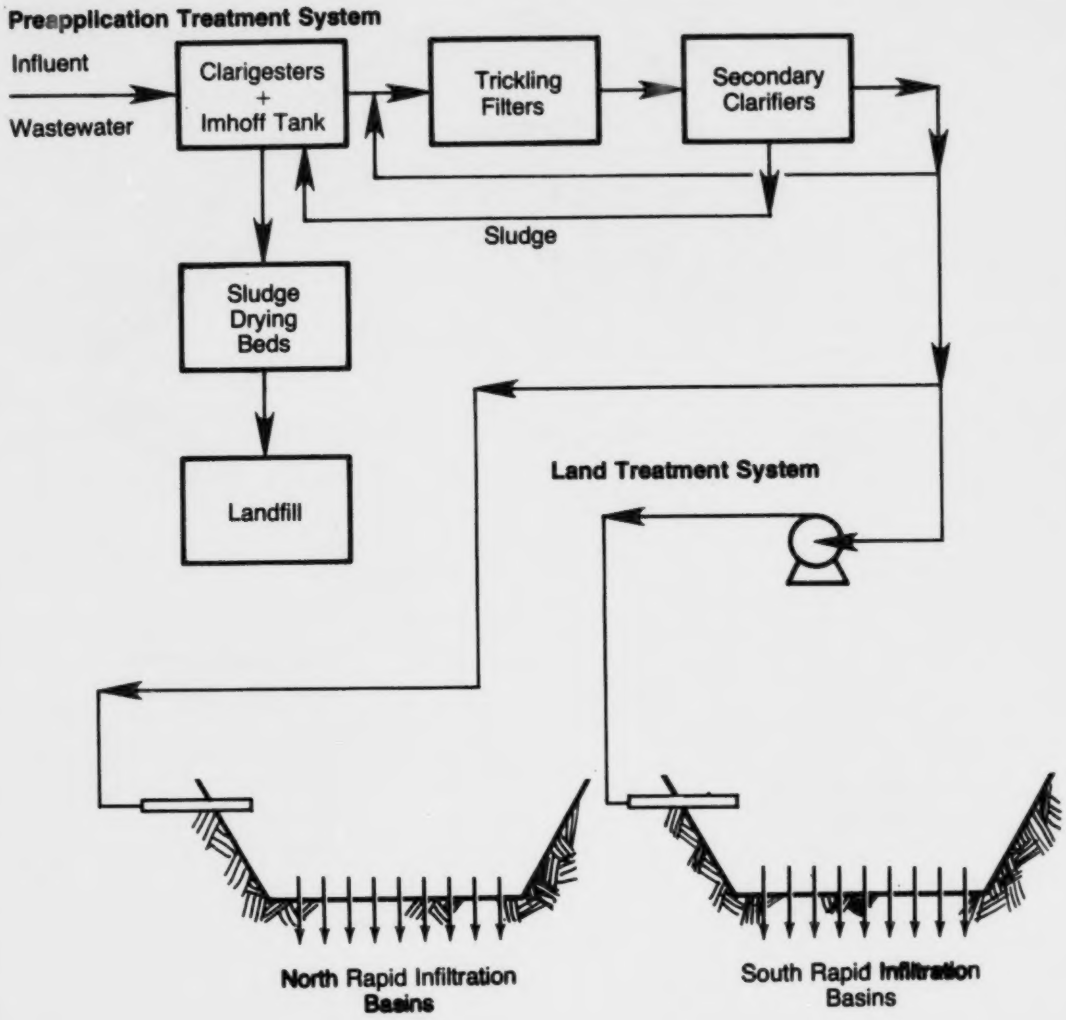

Preapplication Treatment System
Influent
Wastewater
Clarigesters + Imhoff Tank
Trickling Filters
Secondary Clarifiers
Sludge
Sludge Drying Beds
Landfill
Land Treatment System
North Rapid Infiltration Basins
South Rapid Infiltration Basins

Figure A-2. Process flow diagram of Village of Lake George wastewater treatment plant (# 001), Lake George, New York.

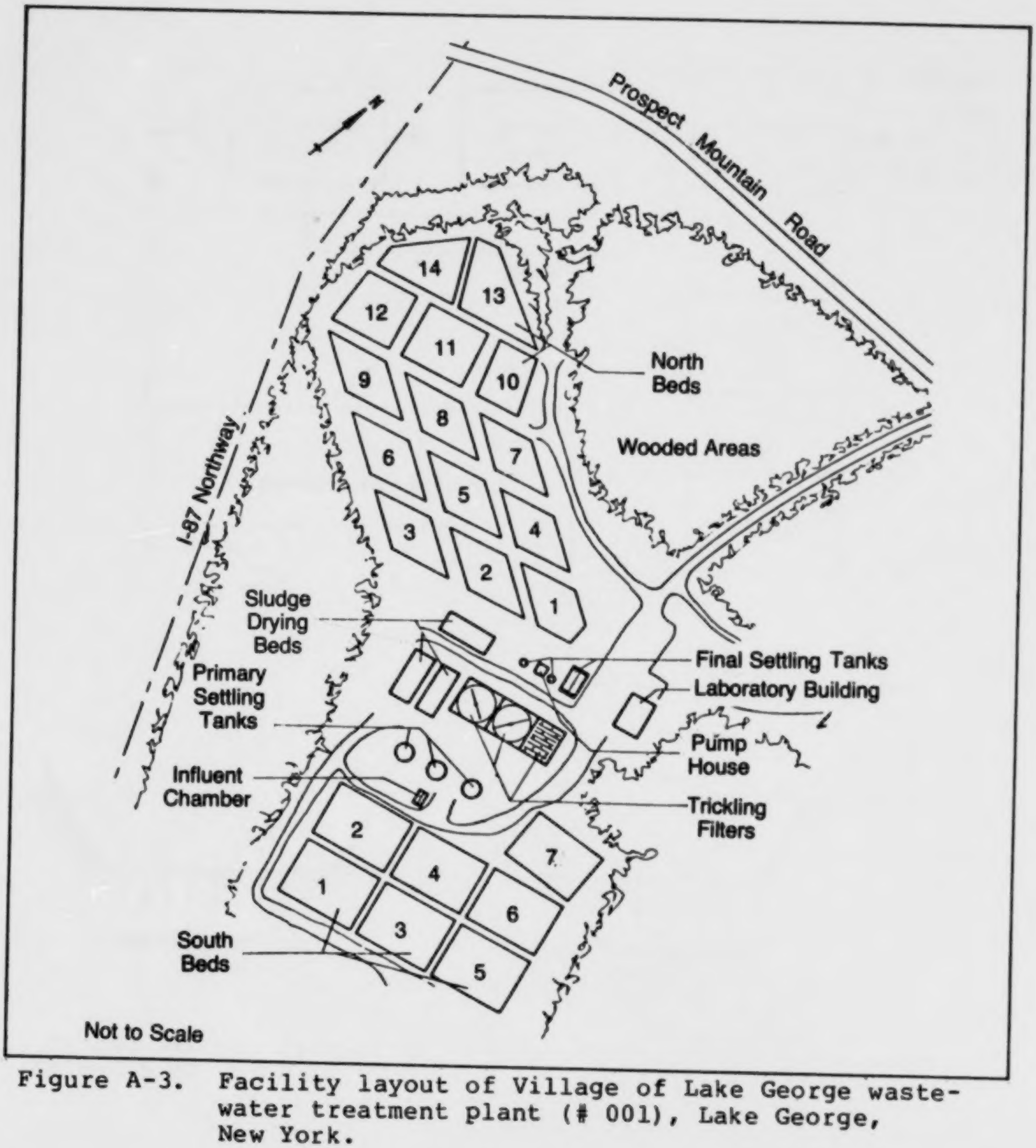

Prospect Mountain Road
I-87 Northway
N
14
13
12
11
10
9
8
7
6
5
4
3
2
1
North Beds
Wooded Areas
Sludge Drying Beds
Final Settling Tanks
Laboratory Building
Primary Settling Tanks
Pump House
Influent Chamber
Trickling Filters
2
4
7
1
3
6
5
South Beds
Not to Scale

Figure A-3. Facility layout of Village of Lake George wastewater treatment plant (# 001), Lake George, New York.

both on- and off-site. The wells are not monitored by the Village of Lake George, but rather have been utilized by researchers from Rensselaer Polytechnic Institute (RPI). Based on additional RPI research, it has been shown that the percolated groundwater follows a path due north (Aulenbach, 1979).

Based on the area involved and the amount of wastewater generated, the following average loading rates have been calculated:

Hydraulic	1.13 m/wk 40.5 m/yr
Organic	23,862 kg BOD_5/ha/yr
Solids	8,897 kg SS/ha/yr

Owing to the different permeabilities of the infiltration beds and operator preferences, the hydraulic loading rates for 1976 varied from approximately 14 to 90 m (46 to 295 ft) (Aulenbach, 1979).

FACILITY OPERATIONS

Due to the highly seasonal wastewater variation caused by the tourist industry, a modular approach to construction and operation of the plant has been taken. Therefore, during the lower winter flows, the Imhoff tank and the two circular trickling filters are taken off-line. For calendar year 1979, effluent BOD_5 and suspended solids averaged 59 and 22 mg/L, respectively, based on weekly 24-hour composites. The BOD_5 value causes the effluent to be categorized as intermediate rather than secondary quality effluent.

Although the rapid infiltration bed operation has been practiced for 41 years and is well defined, it does not follow a prescribed schedule of bed rotation. Normal weekday operation consists of dosing one northern and one southern bed from 8:00 a.m. to 4:00 p.m., and dosing one southern and one northern bed from 4:00 p.m. to 8:00 a.m. the next day. Under normal operation, the level-control pump to the south beds only pumps effluent water which is in excess of the hydraulic capacity of the gravity line to the northern beds. During weekend operation, a total of four beds (two northern and two southern) are dosed for a period of 24 hours. Occasionally during high flow periods, additional beds are pressed into service as required.

The major factor which affects which beds will be utilized is visual inspection, i.e., which bed appears dry. Based on this rotation, the north beds are typically dosed once every 7 to 10 days and the south beds once every 5 to 6 days (as there are fewer beds, they are utilized more often). The ease with which the bed can be dosed is an additional factor affecting bed rotation. For example, a northern bed close to the control building can be dosed by opening one slide gate in one manhole, whereas a more distant bed may require opening three slide gates in three separate manholes.

Under normal conditions a bed will dry in one to two days following wastewater application, depending on size, age, and condition of the bed. Standard operating practice allows a bed to be dry prior to additional wastewater application. During peak flow periods, however, it is often necessary to dose the beds prior to their becoming dry. Research conducted by RPI has qualified the effect of various application sequences with the infiltration rate of the bed (Aulenbach, 1979). Occasionally, sufficient capacity does not exist with the 21 beds, and provisions have been made with a neighboring property owner (ex-sand borrow pit) to dispose of the water on the adjoining property.

Typically, there are no operational problems associated with the rapid infiltration beds. Wastewater distribution continues 12 months per year, and, during the winter months, the wastewater which has frozen merely floats on the newly applied water prior to it percolating into the soil. The ice actually aids the operation as it provides an insulating layer for the soil surface.

During the approximately eight nonwinter months, four laborers spend approximately 90 percent of their time with the beds. Tasks include cleaning the bed (to be described in the next section), mowing the grass and occasional dike maintenance.

Substantial amounts of data exist to document the effectiveness of the Lake George rapid infiltration system (Aulenbach, 1979). In summary, the beds are effective in removing BOD, COD, coliforms, and streptococci in the top 3 m (10 ft), while oxidizing ammonia to nitrate in the same distance. By 18 m (60 ft), nitrate is almost totally removed, whereas ortho-phosphate is almost totally removed at the 7 m (23 ft) depth.

FACILITY MAINTENANCE

Maintenance of the preapplication treatment area is poor, as above-ground superstructures appeared in need of repair and painting. In addition, many of the fixed nozzles were missing from the trickling filter causing poor distribution of wastewater. The control building and laboratory (which are newer) are maintained better. Overall maintenance at the plant may be indicative of the possibility of the plant being abandoned in the near future, and the desire of the Village not to invest additional funds.

The rapid infiltration beds are adequately maintained in terms of berm and hydraulic structure maintenance. North beds 10 through 14 are furthest away from the control building and in the greatest need of additional maintenance. The only mechanical equipment utilized for the infiltration beds (with the exception of trucks and tractors) is the two feed pumps and various valves. The equipment is in adequate condition.

A maintenance problem involves sludge accumulation on the surface of the infiltration beds and subsequent plugging/odor potential, a problem which becomes more acute during the warmer months. During these months, the beds are cleaned approximately once per month, with the cleaning cycle based on visual observations, availability of the bed for cleaning, and time spent by plant personnel on other duties. A crew of four men can clean two beds per day. Bed cleaning consists of first scraping away the surface sludge layer by hand and placing it in a truck. Next, the bed is scraped by a spring tooth implement to scarify the surface 0.15 m (6 in). A tine rake is then used, followed by a drag bar. The bed is then ready to be put back in service. Sand loss is minimal and no attempt at sand replacement is made.

OPERATION AND MAINTENANCE COSTS

A total of $108,645 was spent during fiscal year 1978-1979 for operation and maintenance of the Village of Lake George wastewater treatment facilities. Of this total, $46,246 or 43% was spent on land application, with the major expense being labor. The land application operation and maintenance cost breakdown is as follows:

Personnel	$39,395
Materials and supplies	680
Fuel and electricity	2,246
Insurance	3,347
Vehicle maintenance	578
Total	$46,246

DESIGN DEFICIENCIES

The operating staff at the Village of Lake George reported no known design deficiencies. It is the opinion of the interviewers that:

1. The berms between the infiltration beds should be wider than the existing 1.5 to 1.8 m (5 to 8 ft) to allow truck and tractor access.
2. The plant should have been located at the high point of the site to avoid effluent pumping.

Given the fact that the plant was designed in 1936, however, the need for pumping in 1965 was not anticipated.

NORTH BRANCH FIRE DISTRICT NO. 1
WATER POLLUTION CONTROL FACILITY (# 002)
WEST DOVER, VERMONT

SLOW-RATE SYSTEM

GENERAL

The North Branch Fire District No. 1 Water Pollution Control Facility is located in West Dover, Vermont, approximately 22.5 km (14 mi) north of the Vermont-Massachusetts border (Figure A-4). The plant is owned and operated by the North Branch Fire District No. 1. The facility was visited on March 26 and 27, 1980.

West Dover, Vermont has a cold temperate climate, in part due to the 518-m (1,700 ft) elevation. The mean annual temperature of the Dover area is 6.1°C (43°F), and the average annual precipitation is about 1.4 m (55 in). Average yearly snowfall is in excess of 2.5 m (100 in), whereas yearly average Class A pan evaporation is 0.89 m (35 in).

The North Branch Fire District No. 1 plant is located in a winter resort area (skiing), and therefore receives a seasonal loading. Summer flows average 284 m^3/day (75,000 gpd), and winter flows average 568 m^3/day (150,000 gpd). The plant's design flow is 1,325 m^3/day (350,000 gpd) winter, and 644 m^3/day (170,000 gpd) summer. The plant receives no industrial flow, and the entire flow is associated with either the recreational areas, including lodging, food, and services, or full-time residents. The preapplication treatment facilities consist of two oxidation ditches followed by two secondary clarifiers, chlorination, a polishing pond, and a holding pond. The effluent is applied to 13.8 ha (34 acres) of woodland utilizing spray irrigation in a slow-rate mode.

The preapplication and land treatment systems have both been in operation for five years. Residential, lodging, and commercial facilities are located adjacent to the treatment facilities. There are no immediate plans for modification of the facility.

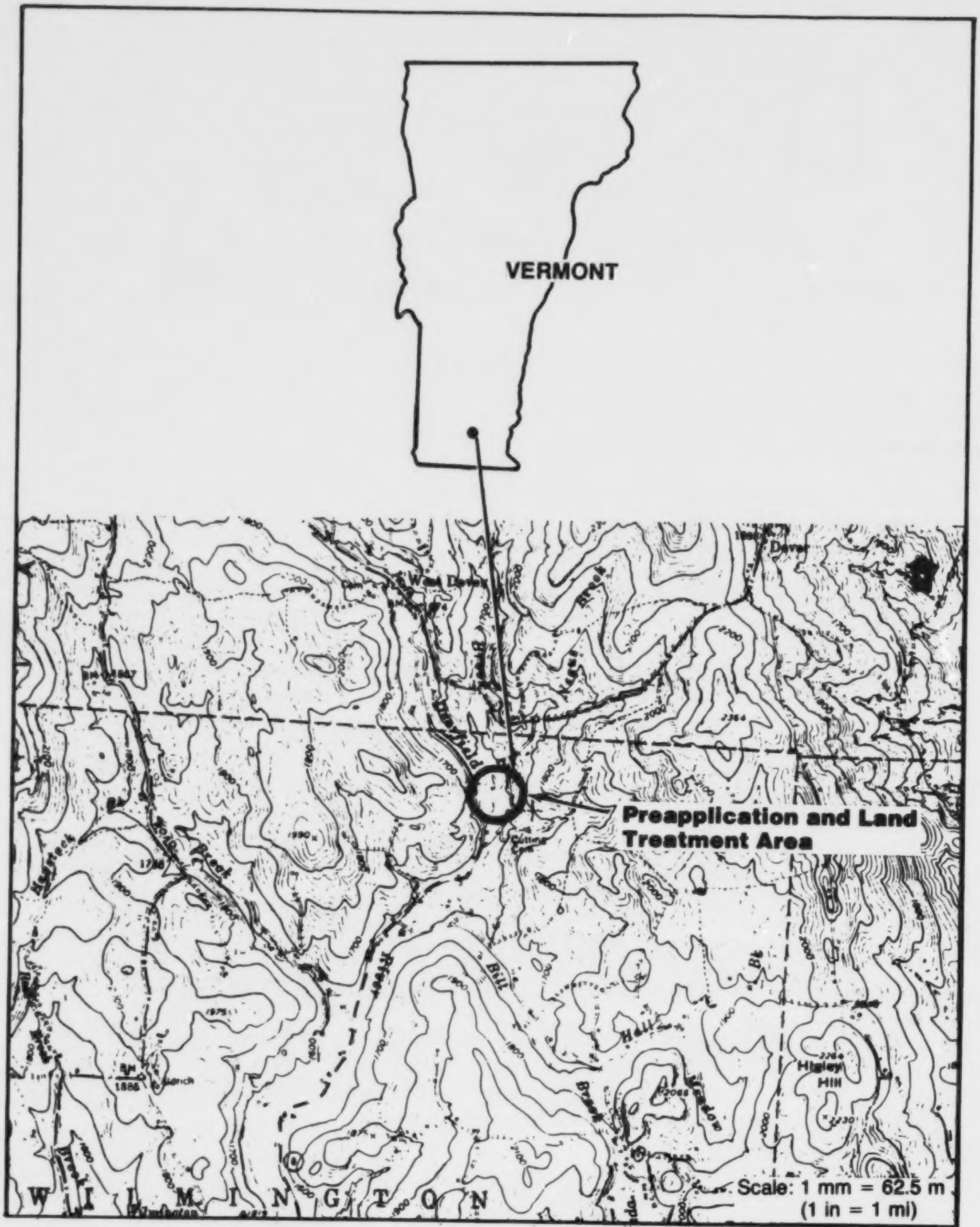

VERMONT
Preapplication and Land Treatment Area
Scale: 1 mm = 62.5 m
(1 in = 1 mi)
WILMINGTON
West Dover
Dover
Higley Hill

Figure A-4. Location map of North Branch Fire District No. 1 water pollution control facility (# 002), West Dover, Vermont.

PHYSICAL FACILITIES

The headworks of the facility consist of a comminutor placed in parallel with a bar screen by-pass channel, and followed by a Parshall flume and a flow proportioning structure (Figure A-5).

There are two oxidation ditches, each 77 m (254 ft) long with a 4.3 m (14 ft) bottom width, an 8.5 m (28 ft) top width, and an average water depth of 1.8 m (6 ft). Each ditch has a 1,673 m^3 (442,000 gal) capacity, and provides approximately 24-hours detention time at average winter design flow. There are two 4.3-m (14 ft) brush aerators in each ditch. The rotors are designed to maintain a minimum velocity of 0.3 m/s (1 ft/s) through the ditches.

There are two secondary clarifiers, each 12.8 m (42 ft) in diameter and 3.0 m (10 ft) deep; each can receive flow from either oxidation ditch. Following clarification, the treated wastewater is chlorinated utilizing gaseous chlorine provided by one of two gas chlorinators utilizing 68-kg (150 lb) chlorine cylinders. The chlorination system is flow proportioned. Waste sludge from the oxidation ditch is stabilized in an aerobic digester, then conditioned with polymer and dewatered in a dual-cell gravity (DCG) rotating screen device. Dewatered sludge is trucked off site and applied to the land.

Following chlorination, the treated effluent flows to a polishing pond. The clay-lined polishing pond has a capacity of 8,330 m^3 (2.2 mil gal) which gives a detention time of four days at the design winter average daily flow. The pond has a maximum depth of 1.5 m (5 ft) and a surface area of 0.7 ha (1.7 acres). The pond stores the chlorinated secondary effluent from the clarifiers until it is sprayed. Any overflow passes by gravity through a pipe to the holding pond. A pump is used to transfer water from the holding pond back into the polishing pond for application to the spray field. When both ponds are full, there are provisions for automatic start-up of the spray system which prevents the polishing pond from overflowing.

The unlined holding pond was constructed over fragipan and has a capacity of 60,570 m^3 (16 mil gal) which gives a design detention time of 29 days. This pond is for storage of the overflow from the polishing pond during periods when spraying is limited or not advisable.

The spray system includes the spray pumps, controls, and a network of spray laterals and nozzles in the spray field. A 0.30-m (12 in) intake line runs from the polishing pond to the three pumps located in the basement of the control building.

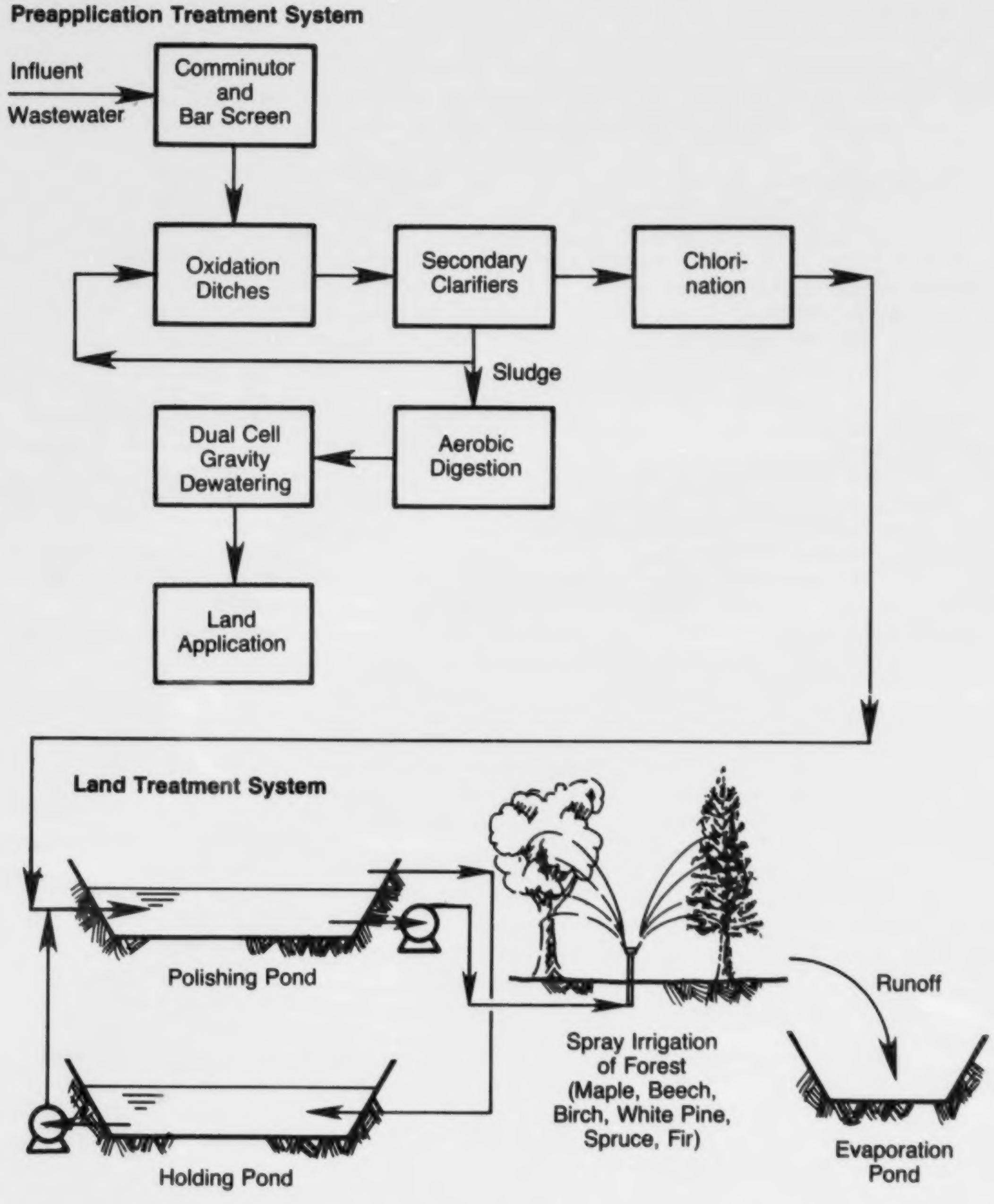

Preapplication Treatment System
Influent
Wastewater
Comminutor and Bar Screen
Oxidation Ditches
Secondary Clarifiers
Chlori-nation
Sludge
Dual Cell Gravity Dewatering
Aerobic Digestion
Land Application
Land Treatment System
Polishing Pond
Runoff
Spray Irrigation of Forest (Maple, Beech, Birch, White Pine, Spruce, Fir)
Holding Pond
Evaporation Pond

Figure A-5. Process flow diagram of North Branch Fire District No.1 water pollution control facility (# 002), West Dover, Vermont.

Each spray pump unit consists of a 1.6-mm (0.0625 in) opening strainer, 37.3-kw (50 hp) pump rated at 0.22 m^3/s (350 gpm), an air-activated automatic control valve, a by-pass line, and a transmitting flowmeter. Each spray pump discharges into a separate header which feeds four of the spray laterals in the spray field. Each spray header has an adjustable, automatically-controlled Camflex spray valve with an accompanying automatically-controlled header drain valve. The drain manifold is piped back into the polishing pond. All header lines run underground from the control building and through the center access trail of the spray site (Figure A-6). Four spray laterals extend from each header in a north-south direction. The 12 spray laterals run parallel to each other, 22.9 m (75 ft) apart, and follow the undulating contours of the spray site. The spray laterals are suspended 1.5 to 4.6 m (5 to 15 ft) above ground, and consist of 51-and 76-mm (2 and 3 in) galvanized quick disconnect steel pipe, insulated by a jacket of PVC pipe. Vegetation is cleared 1.3 to 3.0 m (5 to 10 ft) from either side of each lateral. There are 66 low points in the system where modified Fulljet 3/4 HH6W spray nozzles have been installed. These nozzles spray downward, and rapidly drain the laterals after each spray cycle. In addition, approximately 600 Fulljet 1/4 HH14W nozzles, 7.6 m (25 ft) apart, are also utilized (Bouzoun, 1977). A further discussion of spray nozzles appears later in this report.

There are approximately 13.8 ha (34 acres) of actual spray area covered by the laterals. A 61-m (200 ft) buffer zone separates the spray area from the perimeter of the spray site, bringing the total area of the spray site to approximately 20.2 ha (50 acres).

The spray site is located on a knoll west of the plant. This area is about 518 m (1,700 ft) in elevation, 610 m (2,000 ft) long, and rises 30 m (100 ft) above the plant site. The eastern side of this knoll slopes at an average of 8 to 15% toward the plant site. The western side slopes even more steeply (25%), and extends into a valley cut by the North Branch of the Deerfield River.

A spray field interceptor trench runs southerly along the eastern perimeter of the spray field to the evaporation pond. The purpose of the interceptor trench is to prevent spray field runoff from entering the holding pond, which, under certain weather conditions, can result in repeated pumping and spraying of the same water. Groundwater and surface-water runoff from the easterly-sloping portion of the spray field is collected in the interceptor trench, and flows by gravity to the evaporation pond. Two concrete headwalls are installed in the trench and can be used to divert flow to the holding pond. The evaporation pond is located on the southern edge of the site.

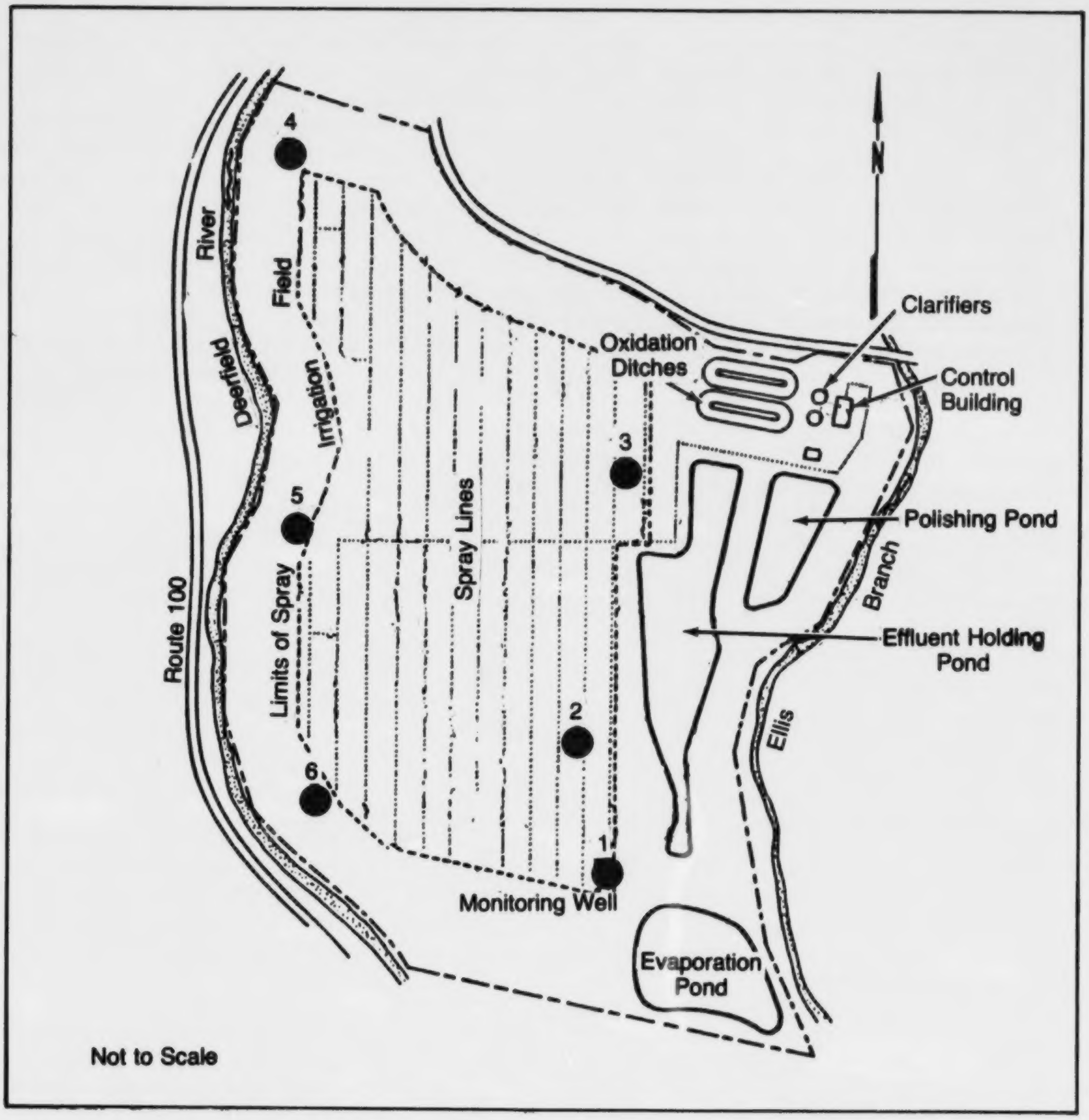

N
Clarifiers
Control Building
Oxidation Ditches
Polishing Pond
Effluent Holding Pond
Evaporation Pond
Monitoring Well
Spray Lines
Limits of Spray Irrigation Field
Deerfield River
Route 100
Ellis Branch
1
2
3
4
5
6
Not to Scale

Figure A-6. Facility layout of North Branch Fire District No. 1 water pollution control facility (# 002), West Dover, Vermont.

The evaporation pond is approximately 91 m (300 ft) square and 1.15 m (3.3 to 5 ft) deep with a design volume of 12,870 m^3 (3.4 mil gal). The flow from the interceptor trench is collected in the evaporation pond where it can percolate into the ground.

Six 102-mm (4 in) groundwater monitoring wells are located in or adjacent to the spray field. The soils at the site are stony, sandy loams containing a low silt and clay content. The soils are underlain by a compacted glacial till (fragipan) which restricts water movement.

About 90% of the spray field is forested. About 40%, primarily the eastern slope, is covered with maples, beeches, and birches, whereas white pine, spruces, and firs dominate the rest of the spray area.

The site loadings are as follows (excluding stormwater runoff which is reapplied):

Hydraulic	1.13 m/yr
	21.8 mm/wk
Organic	40.7 kg BOD_5/ha/yr
Solids	45.2 kg SS/ha/yr
Nutrient	5.4 kg NH_3-N/ha/yr
	63.7 kg NO_3-N/ha/yr
	47.8 kg PO_4/ha/yr

FACILITY OPERATIONS

The preapplication system is well run and produces a quality secondary effluent containing 3.6 mg/L BOD_5 and 4.0 mg/L SS. This is done with only one oxidation ditch and one secondary clarifier in service due to the low flows received at the facility. Both the in-service clarifier and the chlorine contact tank are covered for protection from freezing.

Following biological treatment and chlorination, the wastewater is stored in the polishing pond. When sufficient storage is not available in the polishing pond, the water then overflows to the holding pond. All spraying operations utilize water from the polishing pond, therefore, water is pumped from the holding pond to the polishing pond prior to usage, thereby requiring dual pumping.

The spray pumps and the 12 spray valves are manually or automatically controlled from the operation panel in the control building. A cam/timer system is used to program the desired timing and selection of spray laterals. Under normal operation, the spray system is divided into three sections, each consisting of one spray pump and four headers. At any given time, each pump is pumping to one header in its section. The desired flow to each lateral is determined by the number of nozzles on the lateral, the desired application rate, and the spray schedule. The pump flow meter indicates flow rate, which in turn can be selected by adjustment of the Camflex valve. The cam/timer is then set to alternate between each line in the section. In the summer season, automatic operation typically involves two spray pumps and lines 5 through 12. Each spray pump sprays one of its four lines for approximately 15 minutes each hour until the desired volume has been sprayed. Because of nozzle freezing problems, winter spraying is performed manually with no alternation between lines. Each time spraying terminates in a given line, an automatic drain valve opens, and the manifold is drained back into the polishing pond.

The majority of the operational problems have occurred, not surprisingly, during winter operation of the spray system. The problems can be divided into two areas--downward and upward spraying nozzles. Originally, 66 Parasol 1/2 E40 nozzles were installed at the low points in the system to drain them following their use. While the nozzles effectively drained the lines within one hour, the small quantity of water in the lines would slowly drip out and freeze whenever temperatures were below -3°C (27°F). During the next spray cycle, the nozzles would remain frozen, and the lines could not drain and were susceptible to freezing.

Following a testing program, Fulljet 3/4 HH6W nozzles were installed. The nozzle contains two vanes, one of which is fed through the body of the nozzle itself, whereas the other vane is fed through a brass tube which extends upward out of the base of the nozzle. When the liquid is shut off, the wastewater drains through both vanes. When the level reaches the top of the brass tube, drainage continues through the other vane; however, as the brass tube drains quickly, it remains open. The other vane may freeze, however, when the system is started up, the one vane is open, and the wastewater tends to thaw the second vane open, restoring the nozzle to normal operation (Bouzoun, 1979).

Originally, about 300 Buckner Turf King rotary sprinklers were installed. The nozzles were unsatisfactory as they were susceptible to freezing damage, freezing plugging, and excessive maintenance due to their moving parts and requirement to be kept level. Also, the nozzles sprayed 16.8 to 19.8 m (55 to 65 ft), whereas the trees were only removed from an area approximately 3.0 to 6.1 m (10 to 20 ft) wide. To alleviate the problem, Fulljet 1/4 HH14W nozzles located at 7.6-m (25 ft) intervals replaced the rotary sprinklers which were located at 15.2-m (50 ft) intervals.

After installation of the downward nozzles, spraying was accomplished successfully at temperatures as low as -17.8°C (0°F). In addition, continuous use of one spray line per day was instituted rather than automatic switching.

A third operational headache is the build-up of snow and ice mounds under the spray nozzles. The snow and ice mounds become so large that they actually engulf the spray lines, causing sags and subsequent freezing and bursting. The ice mounding problem was attacked in two ways. One way was to simply go out with axes and chop away the ice, an effective but dangerous method. A second solution was the installation of copper risers approximately 0.91 m (3 ft) long, which could be angled to help minimize problems. Both solutions are currently being utilized.

During summer operation, various Buckner nozzles are reinstalled, and various downward nozzles removed to improve wastewater distribution. In addition, during warm weather spraying is carried out during evening hours to utilize the off peak, less expensive electricity.

FACILITY MAINTENANCE

Overall facility maintenance and housekeeping was very good. One maintenance problem involves spray nozzle plugging. The plugging occurs infrequently, and is usually due to leaves, twigs, or salamanders, and not wastewater particles. A second maintenance problem involves settling of the spray line system. The wood poles supporting the system were driven in, and they occasionally sink. This causes a low spot in the pipe, and a downward spray nozzle must be installed.

In terms of staffing, of the approximately eight man-days per week spent at the facility, four days are associated with land application operation and maintenance. During the winter, the majority of the time is spent removing the ice mounds, whereas in the summer the most time is spent with woodland management.

OPERATION AND MAINTENANCE COSTS

A total of $58,450 is spent yearly for operation and maintenance of the North Branch Fire District No. 1 Water Pollution Control Facility. Of this total, one third is incurred due to the land application system. A cost breakdown for the $19,125 spent per year shows that over one half of the expense is for labor, as follows:

Personnel	$10,550
Materials and supplies	620
Fuel and electricity	2,510
Insurance	2,805
Communications	90
Administration	1,370
Vehicles	200
Legal	740
Miscellaneous	240
Total	$19,125

DESIGN DEFICIENCIES

The improper nozzle selection is a design deficiency. A second design deficiency involves the way the spray lines were laid out. The lines followed the contour of the hill, thereby creating a large number of low spots. By installing the lines to run up/down the hill, the number of low spots could be reduced substantially.

As designed, the 1.5 to 3.0-m (5 to 10 ft) clearance on each side of the spray lines is insufficient for access, particularly when ice mounds are present and need to be removed. The plant operators believe a 4.6 to 6.1-m (15 to 20 ft) clearing on each side would be sufficient. In addition, plant operators feel that a walking train between two spray lines should be provided so that both lines could be checked simultaneously.

A communication system (probably two-way radios) should be provided between operators in the spray fields and the control room so that spraying can be stopped without walking back to the control room whenever a nozzle needs to be cleaned/replaced.

One other problem involves off-site, uncontaminated stormwater which is diverted into the holding and polishing ponds. For example, in calendar year 1979, the plant only received

128,700 m^3 (34 mil gal), however, sprayed 276,300 m^3 (73 mil gal). This stormwater should be diverted away from the ponds. A final design deficiency involves the need to pump wastewater from the holding pond to the polishing pond, and then to the irrigation system. A simpler approach would permit gravity flow to the pumps from both ponds, minimizing the need and cost associated with dual pumping.

CITY OF HART WASTEWATER TREATMENT FACILITIES (# 003)

HART, MICHIGAN

SLOW-RATE SYSTEM

GENERAL

The City of Hart is located in west-central Michigan, a short distance east of Lake Michigan, approximately 129 km (80 mi) north of Grand Rapids (Figure A-7). Agriculture is the predominant industry in the area, particularly the cherry industry. The facility was visited on 7 and 8 April 1980.

The City of Hart owns and operates the wastewater treatment facility, which receives a large amount of industrial flow. The industries involved share in both the capital cost and operation and maintenance costs of the facility.

The climate in Hart, Michigan is seasonal, with a yearly average temperature of 8.4°C (47.1°F). Mean annual precipitation is 0.83 m (32.74 in) and the estimated annual Class A pan evaporation is 0.94 m (37 in).

The preapplication treatment scheme at Hart consists of aerated lagoons followed by holding/oxidation ponds (Figure A-8). The preapplication effluent is intermediate in terms of degree of treatment. Treated wastewater is then applied to 34.8 ha (86 acres) of farmland, consisting of both woods and weeds/grasses. The system is operated as a slow-rate system.

The Hart, Michigan facilities were designed to handle 0.031 m^3/s (0.7 mgd) of domestic and industrial wastewater. The plant currently receives 0.027 m^3/s (0.61 mgd) of flow, including 0.017 m^3/s (0.39 mgd) of industrial flow. The industrial flow is contributed primarily by fruit and vegetable canning, thereby causing an average influent BOD_5 of 742 mg/L. However, the suspended solids loading is not elevated over typical levels. The facility also receives an unknown amount of stormwater as a portion of the collection system is a combined system.

Reproduced from best available copy.

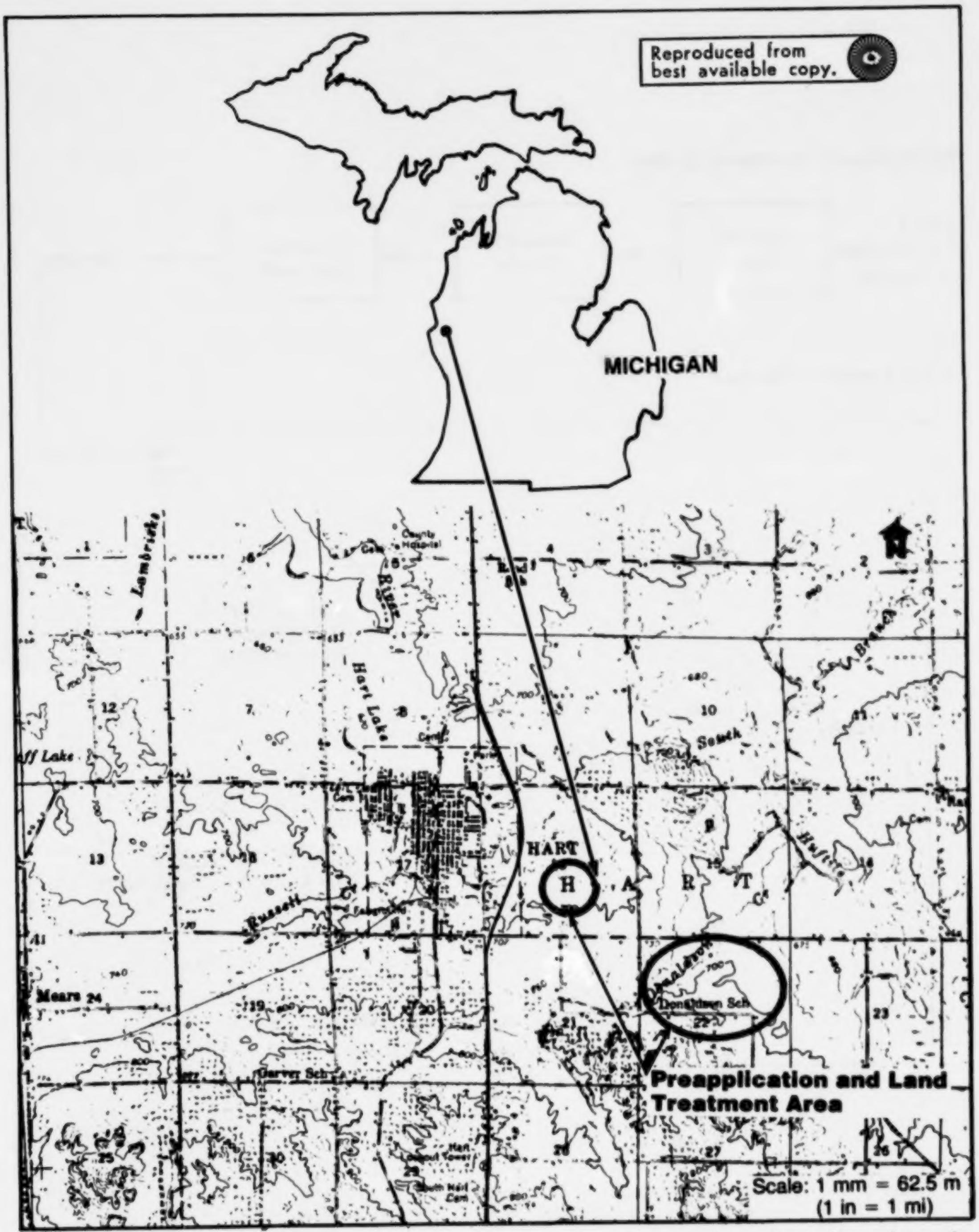

MICHIGAN
HART
H
A
R
T
Hart Lake
South
Branch
Russell
Donaldson Sch
Carver Sch
Meare 24
Preapplication and Land Treatment Area
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-7. Location map of City of Hart wastewater treatment facilities (# 003), Hart, Michigan.

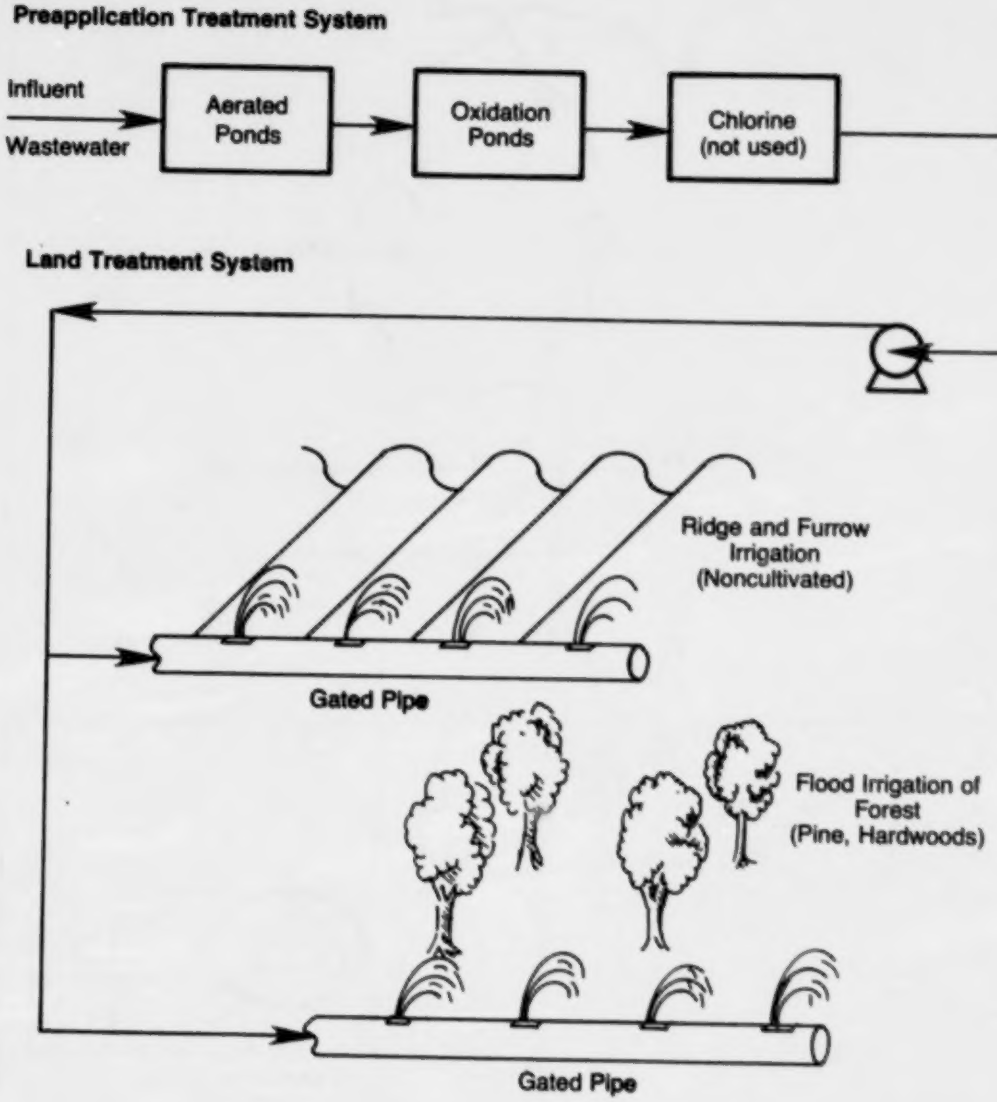

Preapplication Treatment System
Influent
Wastewater
Aerated Ponds
Oxidation Ponds
Chlorine (not used)
Land Treatment System
Ridge and Furrow Irrigation (Noncultivated)
Gated Pipe
Flood Irrigation of Forest (Pine, Hardwoods)
Gated Pipe

Figure A-8. Process flow diagram of City of Hart wastewater treatment facilities (# 003), Hart, Michigan.

The wastewater treatment facilities have been in operation for 15 years. However, expanded and upgraded treatment facilities, along with the land application system, have been in operation for only six years. Future plans for the site call for planting a crop with an economic value. The land use in the vicinity of the site is agricultural.

PHYSICAL FACILITIES

Influent wastewater at the Hart wastewater treatment plant flows directly into one of two aerated lagoons as there is no preliminary or primary treatment. The two lagoons are operated in parallel, and each contains 33,880 m^3 (8.95 mil gal) and a 3.7-m (12 ft) operating depth. At design flow, the detention time is 25.6 days. Each lagoon is aerated by two fixed platform-mounted 37.3-kw (50 hp) surface aerators. As the waste may be deficient in nitrogen because of the industrial contribution, facilities for nitrogen addition are available.

Following the aerated lagoon, the wastewater flows to the three holding/oxidation ponds. The combined volume of the ponds is 313,780 m^3 (82.9 mil gal), and the ponds cover an area of 12.8 ha (31.6 acres). As the ponds store partially oxidized wastewater, they were designed as oxidation ponds. The ponds were designed for series operation and have a 118-day detention time based on the design flow. As the expected winter flow is lower than the summer flow (due to cannery operations), the ponds were designed to contain six months of winter design flow.

Following wastewater storage, the effluent is pumped approximately 2.7 km (1.7 mi) through a 0.25-m (10 in) cast iron force main (Figure A-9) as the soils adjacent to the treatment plant site are unsuitable as they are primarily clay. The effluent is pumped utilizing one of two 44.8-kw (60 hp) centrifugal nonclog pumps. The discharge of the pumps is maintained at 0.057 m^3/s (900 gpm) utilizing a throttling valve to compensate for the different head losses to the various fields, thereby maintaining a constant application rate. A slipstream off the irrigation pumps is used with a gaseous chlorine eductor system to chlorinate the wastewater prior to land application. Owing to the detention time in the wet well and force main, a 40-minute contact time is maintained.

The wastewater is distributed throughout the application site utilizing 0.20-m (8 in) aluminum irrigation pipe headers connected to 0.5-m (6 in) gated aluminum pipe. The sections of gated pipe are 7.6 m (25 ft) long, spaced approximately 30.5 m (100 ft) apart, and are operated at 55 kPa (8 psi). The system is designed so that each gate discharges into a furrow of the ridge and furrow distribution system.

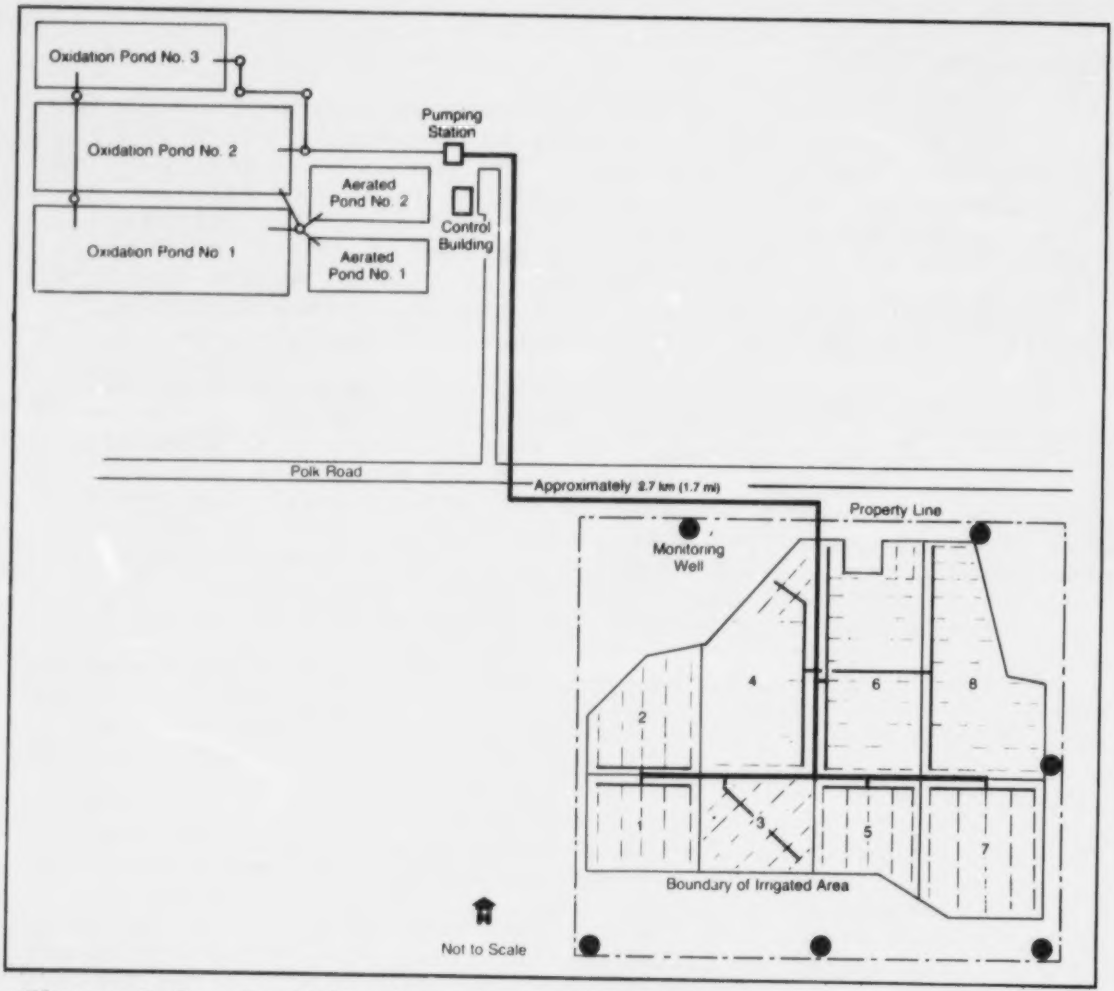

Oxidation Pond No. 3
Oxidation Pond No. 2
Oxidation Pond No. 1
Aerated Pond No. 2
Aerated Pond No. 1
Pumping Station
Control Building
Polk Road
Approximately 2.7 km (1.7 mi)
Property Line
Monitoring Well
1
2
3
4
5
6
7
8
Boundary of Irrigated Area
Not to Scale

Figure A-9. Facility layout of City of Hart wastewater treatment facilities (# 003), Hart, Michigan.

With this irrigation distribution system, approximately 34.8 ha (86 acres) of the total 64.8-ha (160 acre) site can be irrigated. The vegetation on the site includes 20.2 ha (50 acres) of pine trees, 8.1 ha (20 acres) of hardwoods, and 36.4 ha (90 acres) of noncultivated crops/weeds. The irrigation area is divided into eight fields ranging in size from 3.0 ha (7.48 acres) to 6.1 ha (15.16 acres). As designed, an electrically-operated butterfly valve is used to control the flow of wastewater to any one field, based on signals from a controller/timer unit.

The soils throughout the application fields consist of sands and loamy sands. The site was designed with a minimum 15.2-m (50 ft) buffer zone on three sides, and a 61 to 91-m (200 to 300 ft) buffer zone toward the side with residences. A berm system is installed around the perimeter of the site to ensure that the water stays on-site, and that off-site stormwater stays off-site. Six groundwater monitoring wells were installed in conjunction with the land application site. In addition, four domestic wells in the area are monitored.

Based on plant operating data (and assuming precipitation equals evaporation), the following loading rates have been calculated:

Hydraulic	69.5 mm/wk 2.4 m/yr
Organic	1,208 kg BOD_5/ha/yr
Solids	2,101 kg SS/ha/yr
Phosphorus	151 kg PO_4/ha/yr

FACILITY OPERATIONS

The preapplication treatment system produces an effluent with BOD_5 and suspended solids concentrations of 50 and 87 mg/L, respectively. Although ammonia feed facilities were installed, they are currently not being used. As there are no effluent ammonia or nitrate data, it is not known whether more efficient treatment would be possible if the ammonia was added. At the time of the visit, there were strong odors emanating from the oxidation ponds, indicative of the spring turnover of the pond. Although facilities exist for effluent chlorination, unchlorinated water is applied to the irrigation fields.

As originally designed, the irrigation system was to be controlled utilizing a Buckner Sprinkler Company controller which would automatically actuate the header pipe valves and rotate the fields based on a preset rotation schedule. The operators have since disconnected the system, and all irrigation is done manually, based on visual observations. The exact reason for the system being disconnected could not be ascertained due to the turnover in operations personnel, however, the current superintendent believes that operational difficulties caused it to be disconnected. Owing to varying soil permeability, some fields receive more water than others. Wastewater irrigation proceeds from the time the ground thaws until it freezes again, basically from April through November.

A variety of operational problems exist at the Hart facility. The first problem is associated with weeds which fall into the storage ponds during grass cutting, are subsequently drawn into the effluent pumps, and then tend to clog the gated piping, necessitating pipe cleaning.

Two additional operational problems are the result of applying the wastewater to the site, thereby elevating the groundwater table and causing trees to drown and fields to become muddy. These two items can be classified as design related and will be discussed later.

In terms of staffing, the Hart wastewater treatment plant has had a large turnover in personnel, thereby destabilizing plant operations. At the time of the visit, there was no plant superintendent, and one laborer was handling the entire facility. Since then, the superintendent position has been filled, and two full-time people are associated with the plant.

FACILITY MAINTENANCE

Maintenance at the preapplication treatment site was acceptable, in general, with the exception of the access roads, which were extremely muddy and required a four-wheel drive truck to navigate. Although the roads were designed to be all-weather gravel roads, the roads have deteriorated due to the clay soils at the site.

Maintenance of the land treatment site consists of only the above-ground piping, which is basically maintenance free. As discussed earlier, the electrically-controlled valves and control system have been disconnected. There was one gated pipe which had ruptured due to frozen conditions, however, it appears that the system is adequately drained and winterized, as only one section of pipe has been damaged in the six years of operation.

OPERATION AND MAINTENANCE COSTS

A total of $66,057 was spent during fiscal year 1978-1979 by the City of Hart for operation and maintenance of the preapplication treatment and land application systems. Of this total, $10,967 was spent on land application, as follows:

Personnel	$ 3,716
Fuel and electricity	7,251
Total	$10,967

DESIGN DEFICIENCIES

Plugging of the original centrifugal pumps by leaves, weeds, and vegetable and sewage solids caused replacement of these pumps with nonclog centrifugal pumps. The new pumps have worked fine and have not had any problems.

The second design deficiency involves the fact that plans for usage of the irrigation fields were not formalized at the time of construction. Had that been the case, the desired crop could have been planted and potential revenues generated. As things stand now, however, a crop has never been raised, although the possibility exists that hybrid poplar trees for pulp production may soon be planted. As the plans for crop production were never formalized, the necessary earthwork was never done, and low areas on-site have become flooded, and in effect, drowned the pine trees. This has further reduced the potential economic return.

The other design deficiency involves the effect of raising the groundwater table on neighboring properties. Based on visual observations and a conversation with a neighboring farmer, the elevated groundwater table has apparently flooded out a portion of his property, and has caused a portion of his pasture land to be too muddy to use. Therefore, the potential effects of the additional water loading on the existing groundwater table must be adequately assessed if climatic conditions and groundwater table elevation warrant it.

CITY OF FREMONT WASTEWATER TREATMENT PLANT (# 004)

FREMONT, MICHIGAN

SLOW-RATE SYSTEM

GENERAL

The City of Fremont, Michigan is located in west central Michigan, approximately 64 km (40 mi) northwest of Grand Rapids and 32 km (20 mi) northeast of Muskegon (Figure A-10). The treatment plant is owned and operated by the City of Fremont. The plant was visited on April 9, 1980.

The climate in the vicinity of Fremont is seasonal with a yearly average temperature of 7.6°C (45.6°F). The average annual precipitation is 0.81 m (31.85 in), and the mean annual Class A pan evaporation is 0.97 m (38 in).

The Fremont Wastewater Treatment Plant consists of three oxidation ponds in series, followed by comminution, chlorination, and a slow-rate land application system (Figure A-11). Based on analytical data, the oxidation pond effluent is categorized as secondary effluent. The facility was designed to handle 0.036 m^3/s (0.82 mgd), and the current flow rate is approximately 0.013 m^3/s (0.304 mgd). The entire flow received at the facility is of domestic origin.

Both the preapplication and land treatment systems have been in operation for five years. Land use in the vicinity of the Fremont facilities is basically agricultural, with some residences also present. There are no future plans for modification of the facility.

PHYSICAL FACILITIES

Wastewater received at the City of Fremont Wastewater Treatment Plant flows directly into a primary oxidation pond as there are no preliminary or primary treatment facilities. Two additional oxidation ponds are operated in series. The three ponds have a total capacity of 740,050 m^3 (195.5 mil gal). The primary oxidation pond has an area of 16.2 ha (40 acres) and a depth of 1.8 m (6 ft), whereas the secondary pond has an area of

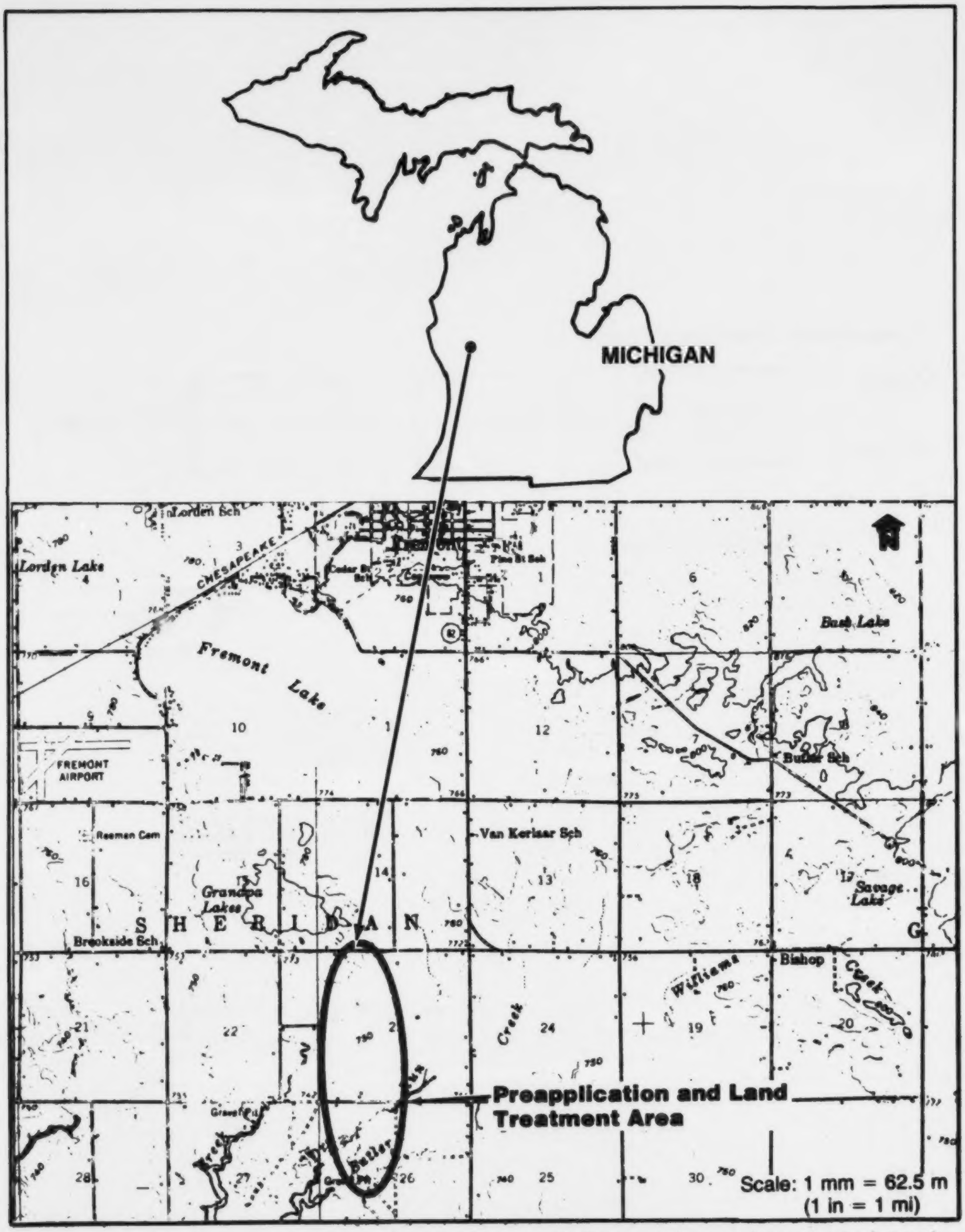

MICHIGAN
Lorden Sch
Lorden Lake
CHESAPEAKE
Fremont Lake
FREMONT AIRPORT
Reeman Cem
Van Kerkaar Sch
Grandpa Lakes
S H E R I D A N
Brookside Sch
Bush Lake
Butler Sch
Savage Lake
Bishop
Williams
Creek
Butler
Preapplication and Land Treatment Area
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-10. Location map of City of Fremont wastewater treatment plant (# 004), Fremont, Michigan.

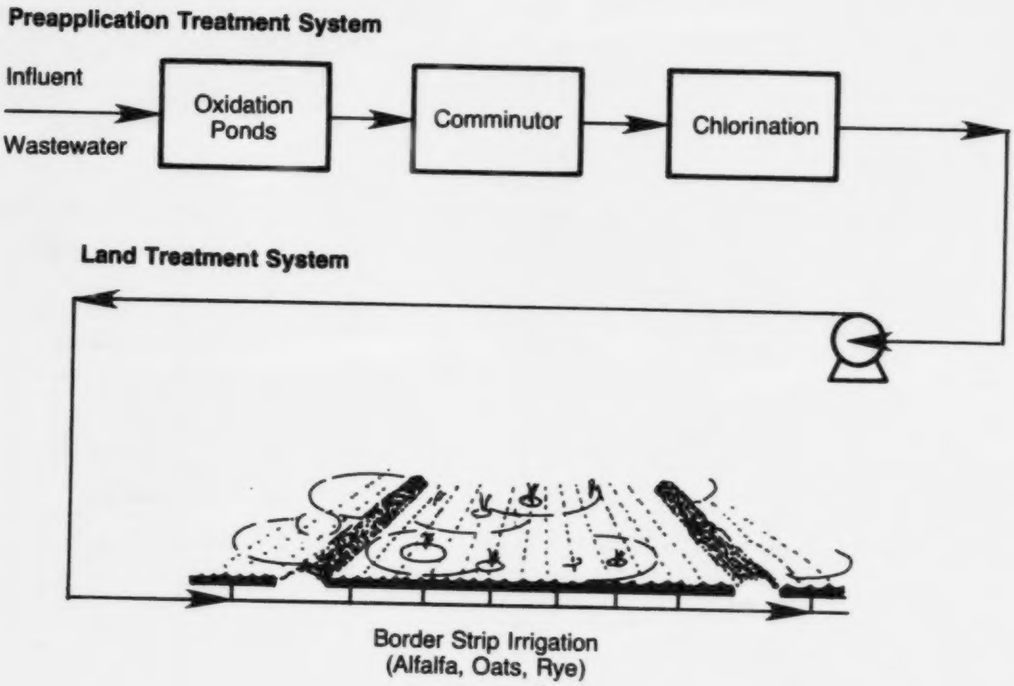

Preapplication Treatment System
Influent
Wastewater
Oxidation Ponds
Comminutor
Chlorination
Land Treatment System
Border Strip Irrigation
(Alfalfa, Oats, Rye)

Figure A-11. Process flow diagram of City of Fremont wastewater treatment plant (# 004), Fremont, Michigan.

8.1 ha (20 acres) and a depth of 2.4 m (8 ft). The tertiary pond also covers an 8.1-ha (20 acre) area, however, the maximum water depth is 3.0 m (10 ft). All three ponds are clay lined.

Following the three oxidation ponds, the wastewater passes through a bar screen and comminutor (located in the berm between the second and third ponds) prior to entering the chlorine contact tank. Gaseous chlorine is supplied from 909-kg (1 ton) cylinders which are located in the control building. The chlorine contact tank also serves as a wet well for the two effluent irrigation pumps.

The effluent pumps are 29.8-kw (40 hp) vertical shaft centrifugal water pumps rated at 0.076 m^3/s (1,200 gpm). The pumps feed the underground distribution system which is constructed of cast iron pipe. Fields close to the chlorine contact tank can also be watered utilizing a gravity discharge. The irrigation area consists of 18 separate fields ranging in size from 5.0 ha (12.4 acres) to 1.0 ha (2.46 acres) (Figure A-12). Typically, each field is divided into 16 to 18 irrigation cells, each cell being approximately 15.2 m (50 ft) wide by 229 m (750 ft) long. The cells are separated/contained by approximately 0.3-m (1 ft) high earthen berms as border strip irrigation is used. The distribution system is valved such that each of the 18 fields can be isolated. In-ground water distribution system-type valves are used. Within each irrigation field, each cell cannot be valved off and all are irrigated simultaneously. Within each cell, a 0.20-m (8 in) cast iron riser pipe with a bell-shaped end imbedded in a 0.91-m (3 ft) square concrete splash plate distributes the water. The inlet structure is located at the head of the field, and wastewater flows down the 2% graded slope. The underground effluent distribution system has built-in drains at the low point in the system. These drains consist of manholes where the pipe can be gravity drained, and then pumped out with a portable pump.

The total irrigation area is 68.4 ha (169 acres) divided into three sets of fields (west, east, and south fields) which are separated by public roads. The entire site is fenced and signs are posted. The soils at the site are basically sand and loamy sand. For the current year, 18.8 ha (46.5 acres) of alfalfa and 5.3 ha (13.0 acres) of rye are being raised, whereas the remainder of the fields are noncultivated.

Based on plant operating records and assuming evaporation equals precipitation, the following loading rates can be calculated:

Hydraulic	2.6 m/yr 76.2 mm/wk

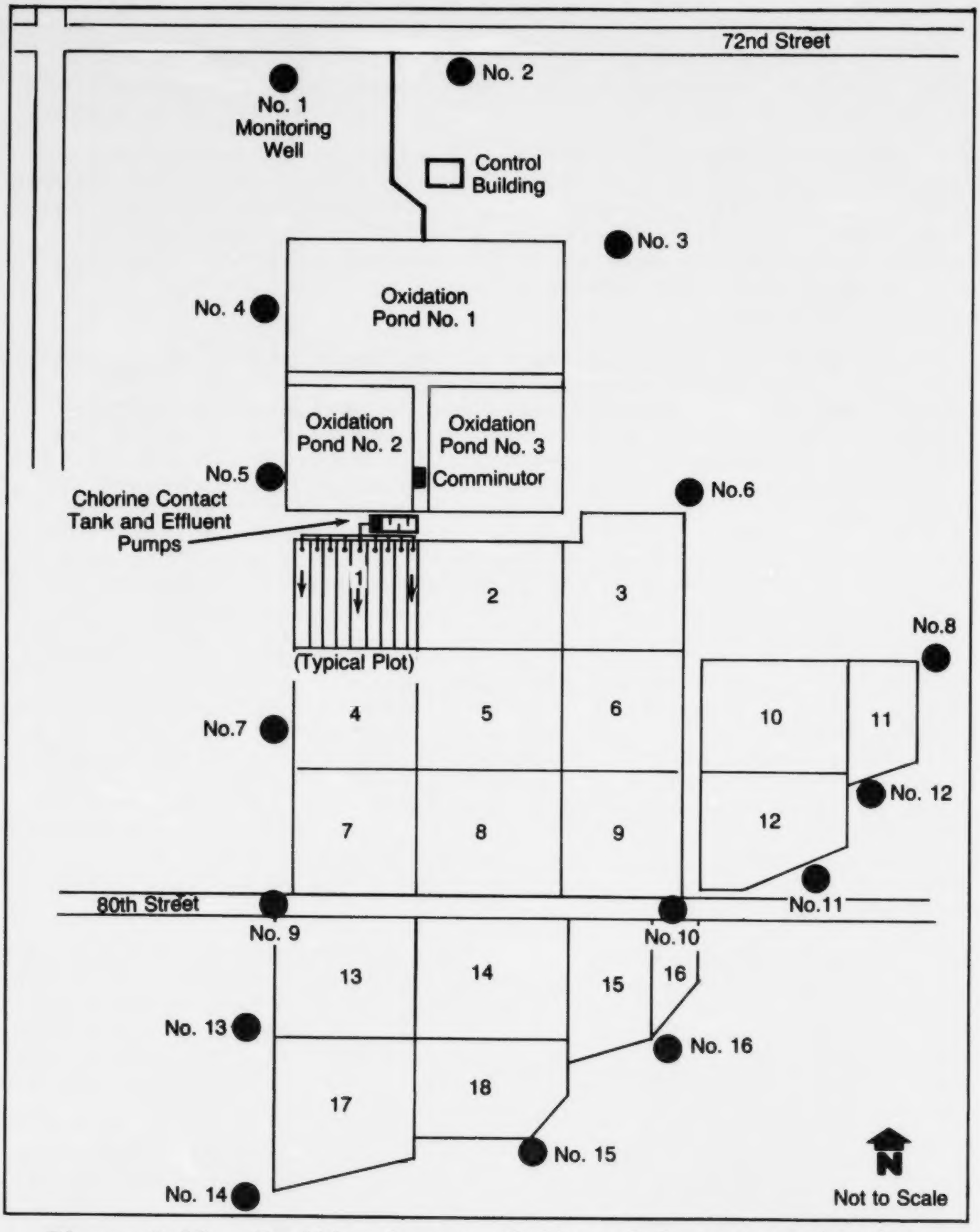

72nd Street
No. 1 Monitoring Well
No. 2
Control Building
No. 3
No. 4
Oxidation Pond No. 1
Oxidation Pond No. 2
Oxidation Pond No. 3
No.5
Comminutor
No.6
Chlorine Contact Tank and Effluent Pumps
1
2
3
(Typical Plot)
No.8
4
5
6
10
11
No.7
No. 12
7
8
9
12
80th Street
No.11
No. 9
No.10
13
14
15
16
No. 13
No. 16
17
18
No. 15
No. 14
N
Not to Scale

Figure A-12. Facility layout of City of Fremont wastewater treatment plant (# 004), Fremont, Michigan.

Organic	316 kg BOD_5/ha/yr
Solids	817 kg SS/ha/yr
Nutrient	87 kg T-P/ha/yr

Although there are no storage ponds on-site, the variable level operation of the oxidation ponds (minimum water depth equals 0.46 m (1.5 ft) affords a storage capacity of 592,100 m^3 (156.4 mil gal) for a holding capacity of 190 days at the design flow rate.

There are 32 groundwater monitoring wells on-site, located at 16 different positions. At each location there is a shallow well, 1.5 m (5 ft), and a deep well, 10.7 m (35 ft). Monthly sampling consists of water elevation, pH, and conductivity, whereas yearly sampling includes chlorine, hardness, alkalinity, ammonia, nitrate, nitrate sulfate, and phosphorus.

Wastewater is applied within 15.2 m (50 ft) of the site boundary, and the buffer zone consists of mowed grass/weeds. As the site is flood irrigated, berms around the fields control any storm runoff.

FACILITY OPERATIONS

The three oxidation ponds are typically operated in series. The preapplication effluent quality is as follows:

BOD_5, mg/L	12
SS, mg/L	31
pH	8.2
T-P, mg/L	3.3
Total coliforms (#/100 ml)	63

The land treatment system is typically operated eight months per year, from April through November. Irrigation commences with the spring thaw and continues until sufficient storage exists in the oxidation ponds, hopefully before freezing weather. Whenever wastewater is applied, the effluent chlorination system is utilized. As discussed previously, only 24.1 ha (59.5 acres) are currently utilized for crop production; the remaining 44.3 ha (109.5 acres) are noncultivated and typically not irrigated. The reason that additional acreage is not utilized is due to the method of irrigation, namely, flooding. In this method, the wastewater is applied until the water reaches the most distant portion of the field. For areas with sandy soils such as the Fremont site, large quantities of water must be applied due to the soil permeability. Therefore, sufficient water is typically not available to irrigate any additional land. Conversely, only water-tolerant crops, such as alfalfa, can be grown, and attempts to grow corn have proved unsuccessful. The alfalfa is used for animal (cattle) feed.

All planting and crop care is done by the Fremont Wastewater Treatment Plant operators. However, crops are harvested by a custom farmer who pays the City $0.35/bale for the alfalfa. Supplemental fertilizers are added when deemed necessary by the facility staff. In terms of crop yield, the alfalfa produces slightly below average yields, possibly due to overwatering.

The operating strategy in terms of wastewater irrigation is to ensure that sufficient storage capacity is available prior to the onset of freezing weather. Therefore, irrigation proceeds four days per week, 24 hours per day, almost independently of weather conditions, at the start of the irrigation season. Toward the middle of the summer, the volume of wastewater remaining to be irrigated is assessed, and irrigation then tends to follow more typical practices, if possible.

On the average, three hours per weekday is spent in conjunction with the land application facility. This time includes both operation and maintenance.

FACILITY MAINTENANCE

The general maintenance plantwide was good. Some problems have been encountered with wind-induced erosion of the oxidation ponds. The problem has been reduced by placing rip-rap along the downwind side of the pond. Some of the rip-rap used is the stone media from the abandoned Fremont trickling filter plant.

The border strip irrigation system is basically maintenance free, and only preventive maintenance of the comminutor and the effluent pumps, along with exercising infrequently-used valves is required.

OPERATION AND MAINTENANCE COSTS

A total of $52,540 was spent during fiscal year 1979-1980 on operations and maintenance. Of this total, 42% ($22,288) was spent on the land application portion, as follows:

Personnel	$ 9,963
Materials and supplies	1,100
Fuel and electricity	2,725
Insurance	500
Maintenance and repairs	8,000
Total	$22,288

The high maintenance and repairs expense is due to the farm equipment (tractors, mowers, etc.) necessary to operate and maintain the facility.

DESIGN DEFICIENCIES

According to plant personnel, top soil which was removed from the irrigation fields during construction was never replaced, thereby decreasing the agricultural value of the soil.

The second design deficiency involves the fact that all 16 to 18 cells within an irrigation field must be irrigated simultaneously as additional valving does not exist. Additionally, if all fields are irrigated concurrently, the aforementioned overwatering problem at the head end of the field becomes even more severe due to the lower hydraulic application rate. To help alleviate this problem, rubber sewer plugs are inserted in the bell end of the irrigation risers, and only eight beds are used simultaneously. In terms of design, the problem can be alleviated by:

1. Installing additional valving.
2. Changing the cell size and/or geometry.
3. Utilizing a different type of distribution system (i.e., spray, or ridge and furrow irrigation.
4. Supplying larger size pumps.

A third design problem involves the need to pump the irrigation water to the irrigation fields. In terms of elevation, the oxidation ponds and chlorine contact tank appear higher than a majority of the irrigation fields. In addition, all wastewater is pumped to the treatment plant. Therefore, the potential for utilizing gravity wastewater irrigation would appear promising.

VILLAGE OF RAVENNA SEWAGE TREATMENT PLANT (# 005)

RAVENNA, MICHIGAN

SLOW-RATE SYSTEM

GENERAL

The Village of Ravenna is located in central Michigan approximately 32 km (20 mi) northwest of Grand Rapids and 32 km (20 mi) due east of Muskegon (Figure A-13). The wastewater treatment plant is both owned and operated by the Village of Ravenna. The facility was visited on April 10, 1980.

The climate of Ravenna is seasonal, and the yearly average temperature is 8.5°C (47.3°F). The yearly average precipitation is 0.80 m (31.53 in), whereas the mean annual Class A pan evaporation is 0.99 m (39 in).

Preapplication treatment at Ravenna consists of two oxidation ponds (Figure A-14). The effluent is then periodically discharged to an 8.1-ha (20 acre) slow-rate land application site. Although there are no analytical data, the plant is assumed to be capable of producing an intermediate level effluent. The plant is designed to treat 341 m^3/day (90,000 gpd). The current flow has been estimated, as no flow measuring device exists, to be 273 m^3/day (72,000 gpd), of which 100% is domestic sewage.

The Ravenna sewage treatment plant and land application system have been in operation 11 years. The facility is located in a basically agricultural area, with residential areas nearby. There are no plans to change the physical facilities of the Ravenna plant in the future.

PHYSICAL FACILITIES

Wastewater generated in the Village of Ravenna is pumped directly to the primary oxidation pond. There are no preliminary or primary treatment operations. The wastewater merely flows into an inlet structure, through a weir, and by gravity into the pond. Each oxidation pond covers 2.7 ha (6.6 acres) and is 2.4 m (8 ft) deep. The ponds are clay lined, and the capacity of

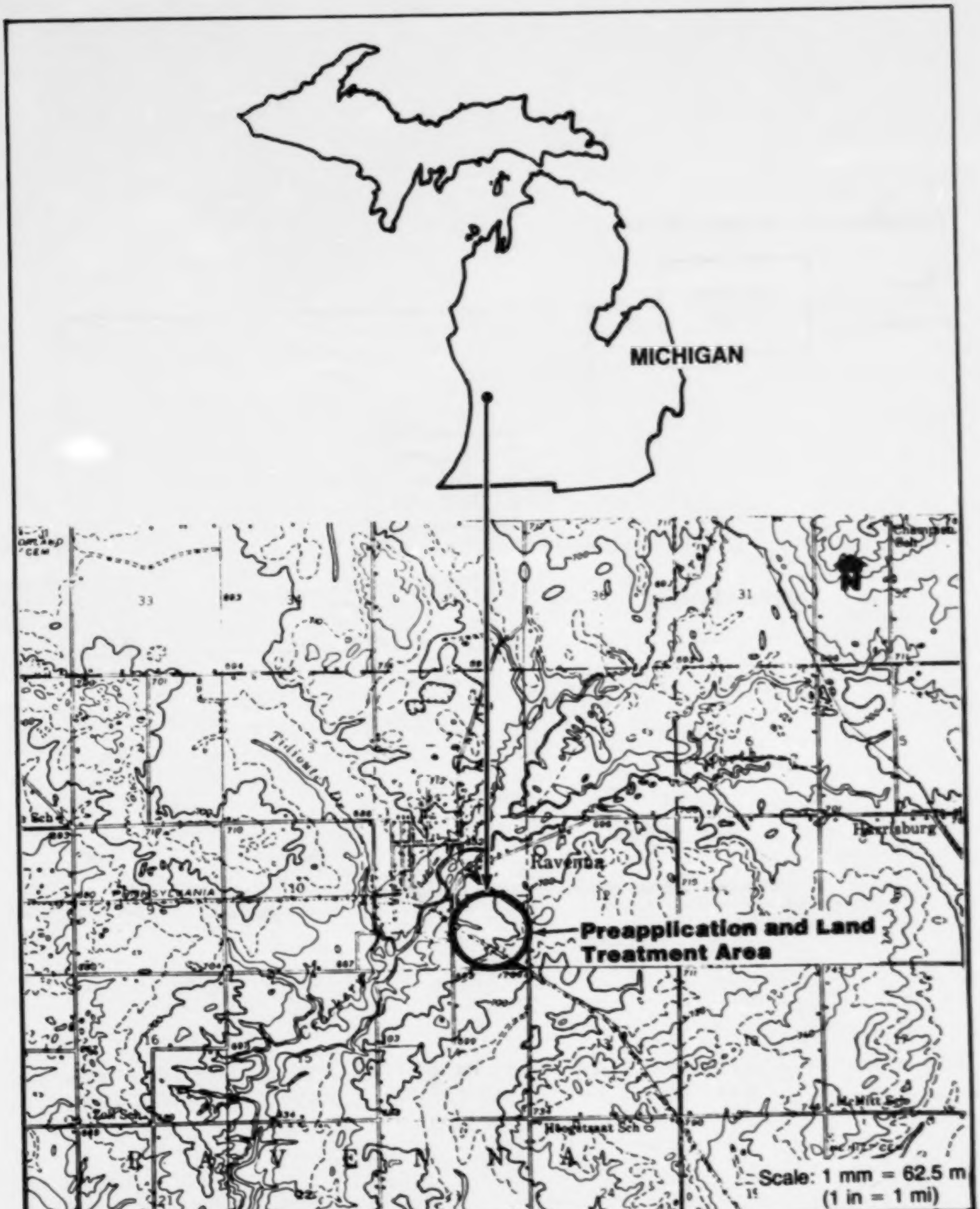

MICHIGAN
Ravenna
Harrisburg
Preapplication and Land Treatment Area
R A V E N N A
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-13. Location map of Village of Ravenna sewage treatment facility (# 005), Ravenna, Michigan.

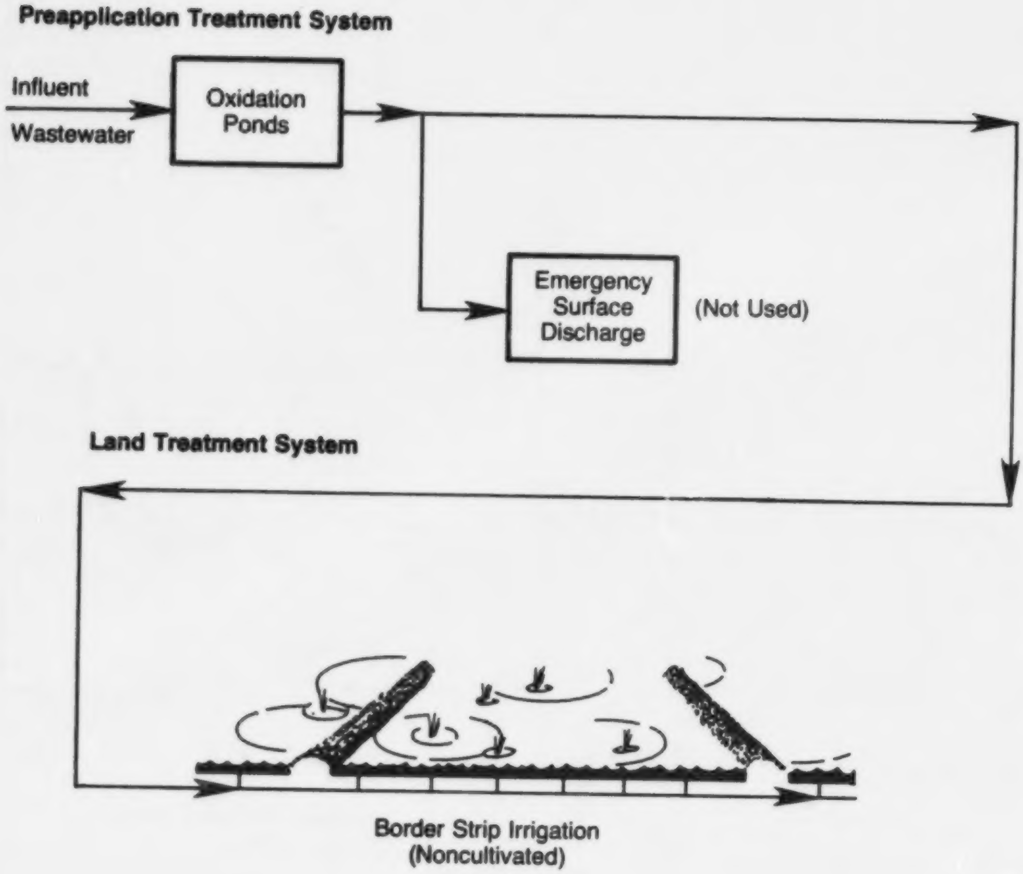

Preapplication Treatment System
Influent
Wastewater
Oxidation Ponds
Emergency Surface Discharge
(Not Used)
Land Treatment System
Border Strip Irrigation
(Noncultivated)

Figure A-14. Process flow diagram of Village of Ravenna sewage treatment facility (# 005), Ravenna, Michigan.

each is 56,780 m^3 (15 mil gal). Based on the design flow, the detention time through both ponds is 333 days.

The land application system consists of one field, divided into two approximately equal-sized fields, with a total area of 8.1 ha (20 acres) (Figure A-15). This area is located east of and at a lower elevation than, the ponds. Therefore all flow to the fields is by gravity. Provisions exist to allow flow from either oxidation pond to be discharged to either field.

The wastewater discharge structure consists of a 0.25-m (10 in) standpipe surrounded by a concrete splash block. One standpipe is located in each field. Provisions also exist for discharge to an adjacent creek/drainage ditch if an emergency situation exists.

There are no groundwater monitoring wells located at the site. A minimum area of 17.4 m (50 ft) separates the application site from adjacent properties. The property is fenced and posted to control public access. Earthen berms are used to contain the wastewater in the field, and to divide the two fields.

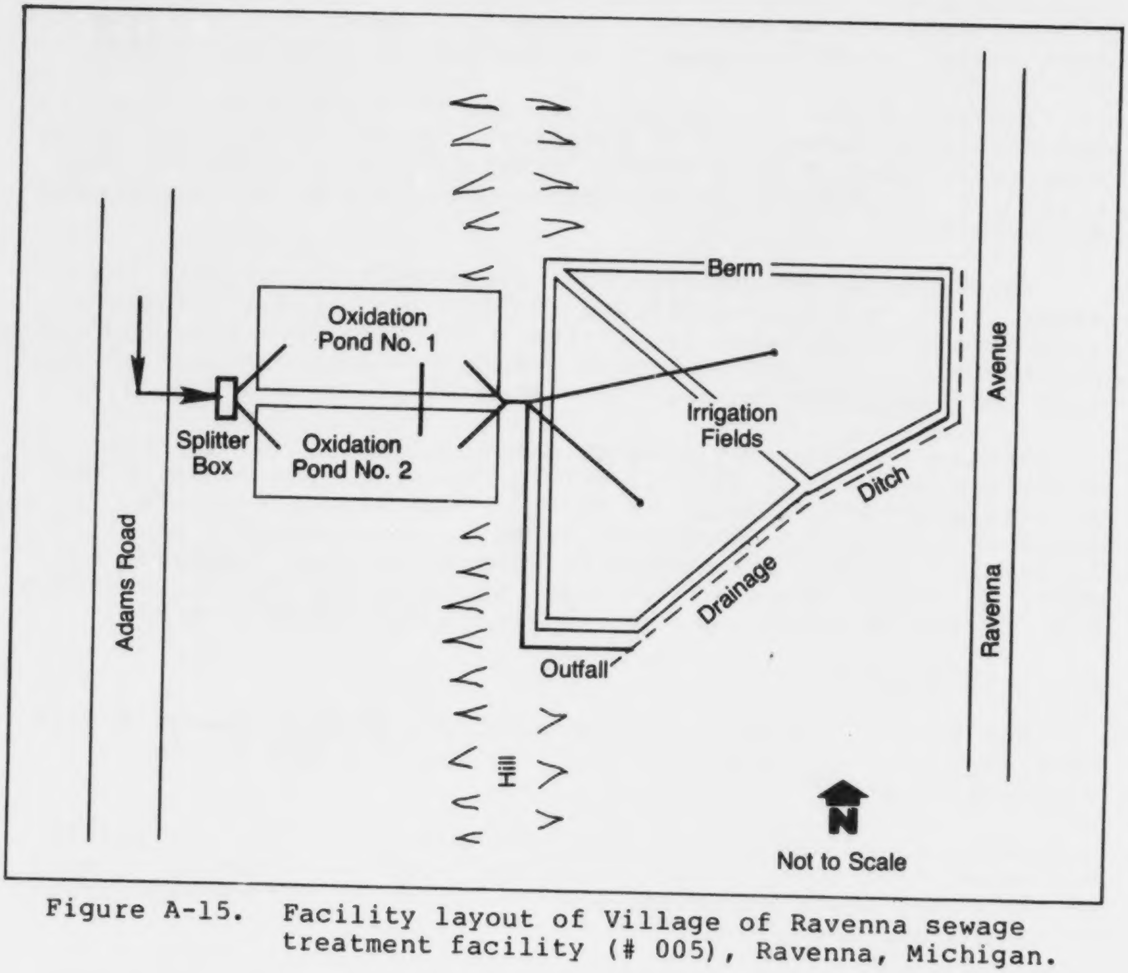
Although no storage pond exists at the site, by maintaining a minimum depth of 0.61 m (2 ft) in the oxidation ponds, a potential storage volume of 82,520 m^3 (21.8 mil gal) exists. Based on boring logs completed prior to construction, the soil in the irrigation site varies from sand, to clay underlain by sand, to clay. There are no crops grown on the fields, and they are covered by weeds and natural vegetation (uncultivated).

FACILITY OPERATIONS

Due to the inherent simplicity of the Ravenna Sewage Treatment Facility, the operations of the facility are fairly straightforward.

There is no analytical sampling requirement for the facility, aside from monthly fecal and total coliform testing. Based on the data, fecal coliforms are typically 10/100 ml and total coliforms are 100/100 ml.

Operation of the oxidation ponds coincides with the operation of the land application system. Each spring after the ice has melted off the ponds and the dissolved oxygen content increases, the slide gate in the secondary oxidation pond is raised, and approximately 1.2 m (4 ft) of water is drained off the pond to either one or both of the irrigation fields. The draining process takes approximately three days.



Adams Road
Splitter Box
Oxidation Pond No. 1
Oxidation Pond No. 2
Hill
Berm
Irrigation Fields
Ditch
Drainage
Outfall
Avenue
Ravenna
N
Not to Scale

Figure A-15. Facility layout of Village of Ravenna sewage treatment facility (# 005), Ravenna, Michigan.

Following this application of water, it typically takes approximately four weeks for the water to percolate into the soil.

After the water is removed from the secondary oxidation pond, 1.2 m (4 ft) of water is transferred from the primary oxidation pond to the secondary oxidation pond. Influent flow then continues to fill up the primary pond for the next six months until fall, when the pond is nearly full. Once again the same process is repeated, namely, 1.2 m (4 ft) of water is applied to the fields, and the water transferred from the primary to the secondary oxidation pond. It should be noted that a new superintendent has been appointed, and attempts at applying wastewater throughout the warmer months will be made during 1980.

Based on this twice a year application to the 8.1 ha (20 acres) and assuming precipitation equals evaporation, approximately 0.61 m (24 in) of water is applied each time for a total of 1.2 m (4 ft). Due to the soils at the site, however, the field which is mostly sand receives more water than the field which is predominantly clay.

There are no crops currently grown on the fields; however, the Future Farmers of America attempted to plant a corn crop for harvest, but were not successful. At the time of construction, some trees were left in the irrigation field, however, as the fields were regraded, the trees were left with "islands" of soil around them. The trees have since died and should be removed.

The total staffing for the entire facility requires approximately 10% of the combined time of the superintendent, operator, and one summer employee. The remaining 90% of their time is spent on other duties in the Village. Of the time spent at the plant, approximately 10% is spent on operations and maintenance of the land application system.

FACILITY MAINTENANCE

With the exception of a few valves, there is no mechanical equipment associated with either the preapplication or land treatment systems. The only maintenance problems appear to be associated with the oxidation ponds, relating to some dike erosion and sludge build-up problems. Crushed stone has been placed on the berm to minimize the wind-induced erosion. In addition, flooding the irrigation fields appears to cause a seasonal increase in the mosquito and muskrat populations.

OPERATION AND MAINTENANCE COSTS

A total of $12,200 was spent during calendar year 1979 on operation and maintenance of the Village of Ravenna Sewage Treatment Facility. Of particular interest is the fact that no electricity is used in the process, and in fact, no electricity is available on-site. A total of $1,900 or 16% of the total budget is spent on land application per year, consisting of:

Personnel	$ 300
Insurance	1,000
Vehicle and tractor rental	600
Total	$1,900

DESIGN DEFICIENCIES

The erosion around the banks of the oxidation pond could have been prevented by installing rip-rap on the downwind sides of the berms. In addition, staff gauges in the ponds would simplify operation of the facility.

More uniform grading of the irrigation field would be desirable and would improve wastewater distribution, and minimize the ponding which currently occurs. Additionally, the trees should have been removed at the time of construction. The operators also believe that higher berms should have been constructed so that more water could be applied at one time, however, this need is caused by historical operating practices rather than a design problem.

CITY OF WAYLAND WASTEWATER TREATMENT PLANT (# 006)

WAYLAND, MICHIGAN

SLOW-RATE SYSTEM

GENERAL

The City of Wayland, Michigan is located in southwest Michigan approximately 32 km (20 mi) due south of Grand Rapids (Figure A-16). The City of Wayland Wastewater Treatment Plant is owned and operated by the City of Wayland. The facility was visited on April 11, 1980.

Wayland, Michigan has a seasonal climate, with the yearly annual temperature averaging 8.8°C (47.8°F). The average annual precipitation is 0.32 m (32.39 in), and the mean annual Class A pan evaporation is 1.02 m (40 in).

The Wayland Wastewater Treatment Plant current influent flow rate is 0.011 m^3/s (0.25 mgd), of which approximately 20% is due to a food product plant. The treatment facilities consist of an aerated lagoon and two oxidation ponds, all operated in series (Figure A-17). The effluent is chlorinated and applied to 31.6 ha (78 acres) of cropland utilizing spray irrigation. The land treatment system is operated in a slow-rate mode. The plant was designed to handle 0.022 m^3/s (0.5 mgd) and the entire system has been in operation nine years.

The facility is located in an agricultural area. Plans for future modifications call for installation of additional tile drain fields.

PHYSICAL FACILITIES

The influent to the Wayland Wastewater Treatment Plant flows directly to the aerated lagoon and is not subject to any preliminary treatment. The aerated lagoon covers an area of 0.4 ha (1 acre), is 4.4 m (14.5 ft) deep, and is mixed by an 18.7-kw (25 hp) floating surface aerator. The detention time in the lagoon is approximately 19 days at the current flow rate.

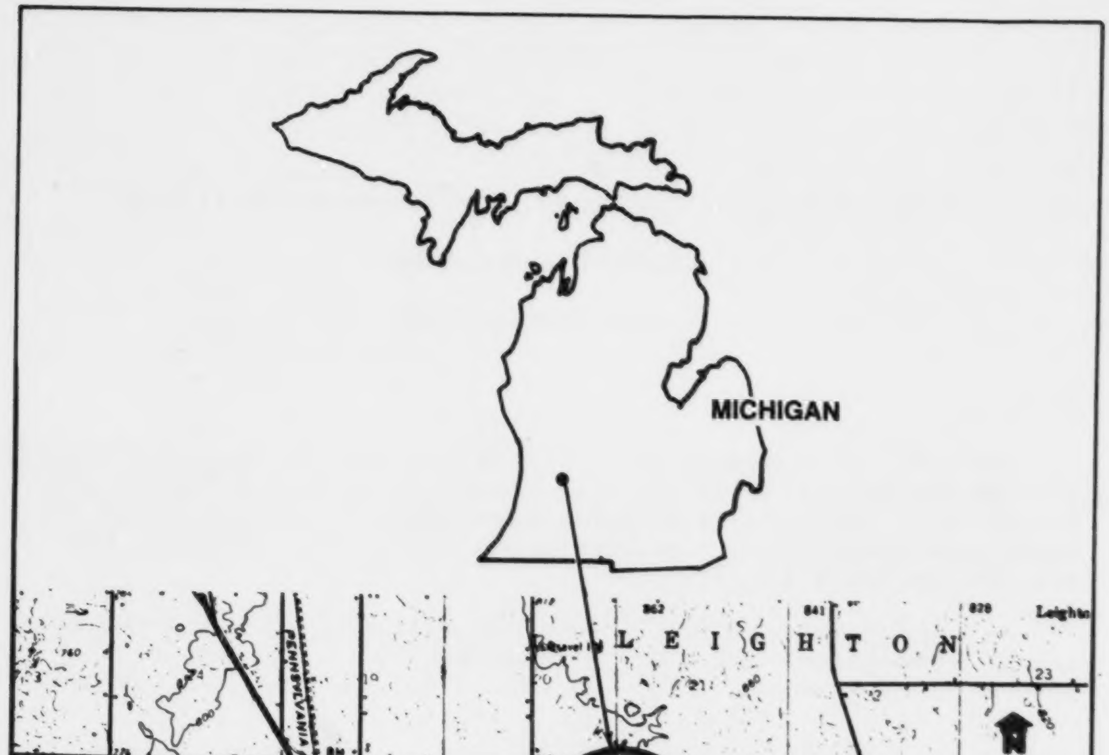

MICHIGAN
L E I G H T O N
Preapplication and Land Treatment Area
Wayland
Hill Lake
Wayland Landing Field
PENNSYLVANIA
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-16. Location map of City of Wayland wastewater treatment plant (# 006), Wayland, Michigan.

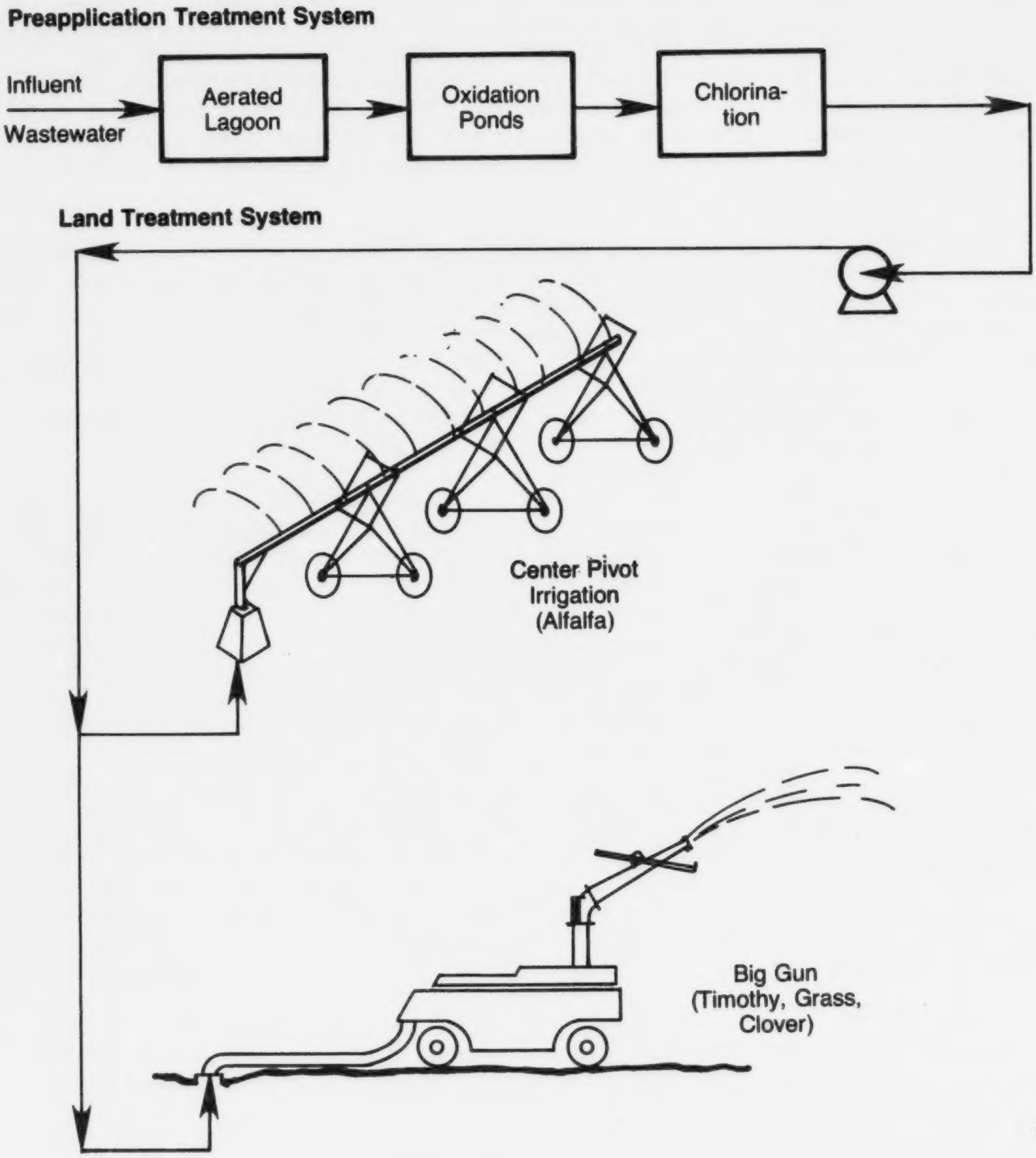

Preapplication Treatment System
Influent
Wastewater
Aerated Lagoon
Oxidation Ponds
Chlorination
Land Treatment System
Center Pivot Irrigation (Alfalfa)
Big Gun (Timothy, Grass, Clover)

Figure A-17. Process flow diagram of City of Wayland wastewater treatment plant (# 006), Wayland, Michigan.

The wastewater overflows the aerated lagoon into the first of two oxidation ponds operated in series. Each pond covers 6.1 ha (15 acres), and is 2.6 m (8.6 ft) deep, corresponding to a volume of 159,000 m^3 (42 mil gal). The interpond flow is by gravity, and is controlled by a manually-operated gate valve. Although there are no storage ponds, the difference between minimum and maximum operating levels results in the two oxidation ponds providing a potential total storage of 226,000 m^3 (59.6 mil gal).

Treated wastewater flows by gravity from the oxidation ponds to a chlorine contact tank, where a gaseous chlorine solution is added. The contact tank consists of a vertical lined section of corrugated metal pipe. The chlorinated effluent then flows to a pump station containing two 29.8-kw (40 hp) centrifugal pumps with a total capacity (both pumps) of 0.057 m^3/s (900 gpm). The pumps supply two irrigation systems: a center pivot spray irrigation rig, and an end-tow big gun unit (Figure A-18).

The center pivot rig (Gifford-Hills Model No. 360) is 207 m (680 ft) long and consists of five sections, each section being driven by an individual electric motor. The rig makes one revolution every 24 hours and covers a 13.8-ha (34 acre) plot. The end-tow big gun unit (Viemar) utilizes a 36.8 mm (1.5 in) nozzle, operates at 620.6 kPa (90 psi), and covers an area 73.2 m (240 ft) wide on each pass. The big gun can be operated from any one of various standpipes and can irrigate a total area of 22.3 ha (55 acres) located either east of the oxidation ponds or adjacent to the center pivot field.

The soils in the spray application site vary from a clay loam (upper fields) to a sandy loam (lower fields). As the site was utilized as a farm prior to construction of the plant, various areas of the spray fields are underdrained. In addition, wet spots exist in various other areas of the fields, and these areas will soon be underdrained. All water collected by the underdrain system is gravity discharged to a nearby creek.

Assuming an even distribution of effluent among the 31.6 ha (78 acres) that are typically irrigated, and that evaporation from the oxidation ponds equals precipitation, then the site loading is:

Hydraulic	1.1 m/yr 42.2 mm/wk
Organic	287 kg BOD_5/ha/yr

A variety of crops are grown at the Wayland site. Usually a mixture of timothy, alfalfa, and clover is grown on the upper

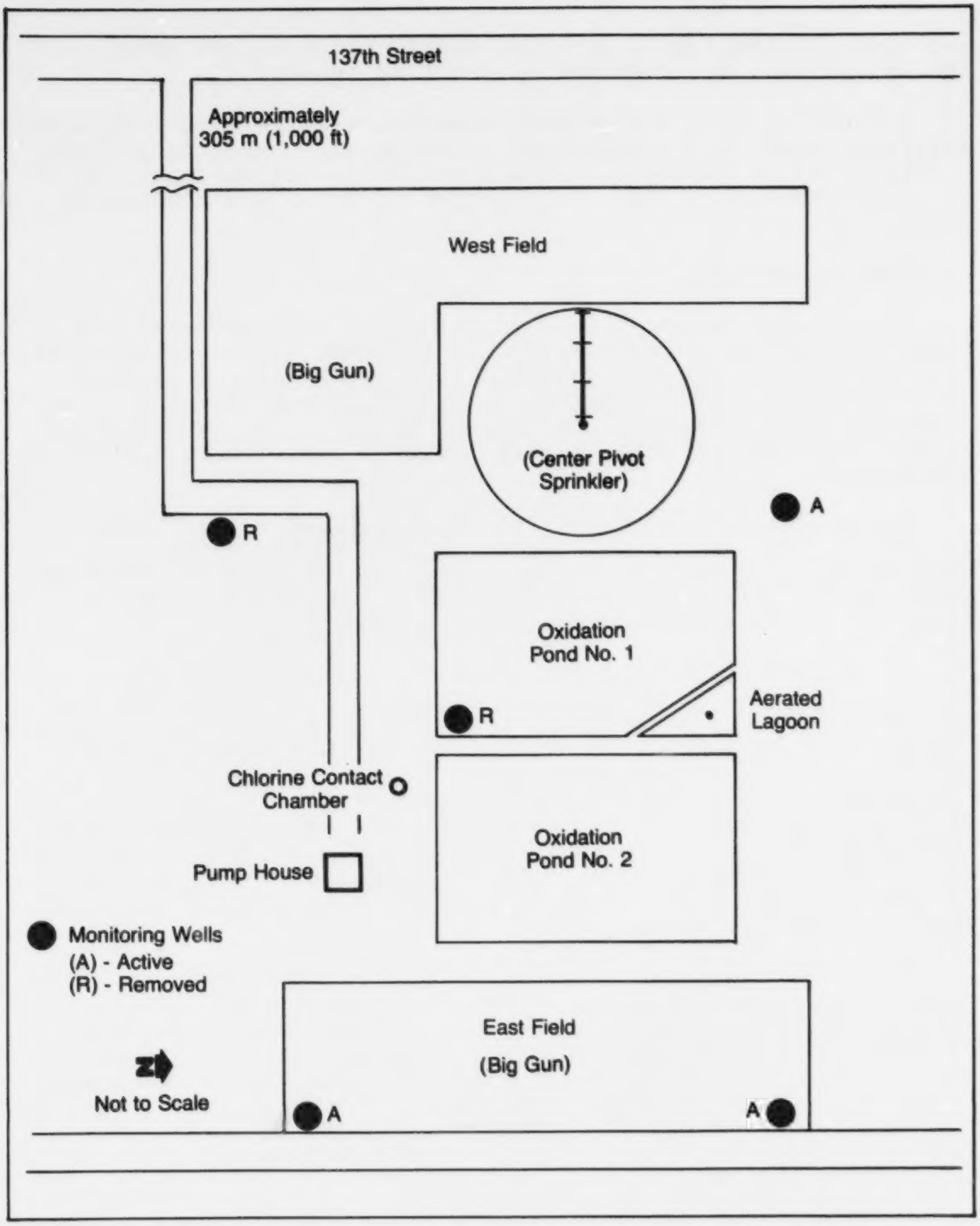

137th Street
Approximately
305 m (1,000 ft)
West Field
(Big Gun)
(Center Pivot
Sprinkler)
A
R
Oxidation
Pond No. 1
R
Aerated
Lagoon
Chlorine Contact
Chamber
Pump House
Oxidation
Pond No. 2
Monitoring Wells
(A) - Active
(R) - Removed
East Field
(Big Gun)
N
Not to Scale
A
A

Figure A-18. Facility layout of City of Wayland wastewater treatment plant (# 006), Wayland, Michigan.

and lower fields. Corn is occasionally grown on the upper fields and will be grown during the 1980 season.

A total of five groundwater monitoring wells were installed initially when the facility was constructed. Owing to various problems (to be discussed later), the wells are currently unusable, and plans exist for installation of three new monitoring wells.

FACILITY OPERATIONS

The preapplication treatment system is well operated and there were no aesthetic nuisances. In terms of operating strategy, the aerated lagoon runs at a constant level and the primary oxidation pond, therefore, constantly receives flow. The secondary pond receives flow intermittently. The chlorination system is in operation only when the land application system is operational.

The oxidation pond final effluent averaged 33 mg/L BOD_5 for 1979. BOD_5 is the only parameter monitored, being measured twice per year. As the suspended solids from an oxidation pond are typically greater than 30 mg/L, the system is categorized as having an intermediate effluent quality.

Prior to 1980, all of the wastewater distribution and crop planting was done by the plant staff. All crop harvesting and baling was done by a custom farmer who received the baled hay as pay for the cutting. Typically, three to four cuttings of hay per season are realized. Starting in 1980, however, a farmer has leased the 31.6-ha (78 acre) site (three-year lease for $1,000). The City will be responsible for wastewater application only, and the farmer will plant, cultivate, and harvest the crops. The farmer may not interfere with the wastewater application, however. Corn is to be planted in the east field, with the crop used for animal feed.

In terms of wastewater application strategy, water is typically applied seven days per week, 24 hours per day from April through September. The criteria for initiating wastewater application is waiting approximately 30 days after the ice melts off the oxidation ponds to allow time for the dissolved oxygen level in the pond to rise. Application continues until there is 0.76 m (2.5 ft) of liquid in the second oxidation pond. Hopefully, the desired level in the pond will be reached prior to subfreezing weather.

Operation of the irrigation equipment requires approximately one hour per day. The large majority of this time is associated with moving and setting up the end-tow big gun sprinkler, as the center pivot requires little or no operational attention. As the big gun moves at approximately 0.3 m/min (1 ft/min) and the length of the field is 0.8 km (0.5 mi), it takes approximately two days for the traveling sprinkler to traverse the field.

A major operational problem is associated with having to move the traveling gun. At the start of each run, a tractor is moved to the far end of the field, and the cable from the moving sprinkler connected. A gas-powered winch on the tractor then pulls the sprinkler cart across the field. Upon reaching the tractor, the cart is disconnected, the tractor moved to the other side of the field, the cable reconnected, and the process repeated. Initially as designed, the winch was connected to an eyelet embedded in concrete, however, on reaching the far side, the cable could not be disconnected due to the tension in the line. The tension was due to the 102-mm (4 in) hose which was stretched across the field, full of water, and unable to be easily drained. Therefore, the tractor is used as it can be taken out of gear and moved forward. Regardless of the method used, substantial periods of time are required to move the traveling sprinkler.

FACILITY MAINTENANCE

Overall maintenance at the Wayland Wastewater Treatment Plant was good. One of the major maintenance problems has been wind-induced erosion along the banks of the oxidation ponds. This problem has been ingeniously solved by grouting used pieces of concrete sidewalk on the banks of the pond.

A second maintenance problem was caused by the center pivot sprinkler wheels which made deep ruts in the clay loam soil of the upper field, making operation of the unit impossible. The problem was solved by excavating the wheel paths and filling them with gravel.

OPERATION AND MAINTENANCE COSTS

A total of $27,560 per year is spent for operation and maintenance of the facility. Approximately 29% of the total budget is associated with land application. The land application cost breakdown is as follows:

Personnel	$2,200
Fuel and electricity	1,750
Insurance	500
Maintenance and repairs	2,000
Equipment rental	1,500
Total	$7,950

DESIGN DEFICIENCIES

The inability of the on-site monitoring wells to supply a sufficient volume of water to sample is a design deficiency. The problem is believed due to the wells being either too deep or too shallow (i.e., not in upper groundwater table), or simply too small -- the wells are only 32 mm (1.25 in) in diameter.

A second design problem involves the wind-induced erosion on the downwind banks of the oxidation pond. The problem is currently being corrected by grouting in pieces of broken concrete sidewalk.

An additional design deficiency is associated with the choice of irrigation equipment. The center pivot sprinkler was chosen for the east fields which are dominated by clay soils, and the aforementioned traction and sinking problems have been common. Compounding the problem is the fact that the unit is constructed of steel, whereas aluminum would only weigh about half as much. For the west fields, the traveling gun sprinkler was chosen and the operational problems have already been discussed. Due to the downgradient location of the east field as compared to the second oxidation pond, gravity irrigation utilizing border strip or ridge and furrow planting may have simplified operations and substantially reduced power costs.

One final design deficiency is the lack of a strainer or bar screen prior to the effluent pumps. Various items, particularly turtles, have been drawn up the intake line requiring cleaning of the pump housing and/or piping.

FONTANA REGIONAL PLANT NO. 3 (# 007)

FONTANA, CALIFORNIA

RAPID INFILTRATION AND SLOW-RATE SYSTEM

GENERAL

The Fontana Regional Plant No. 3 is located in Fontana, California, a city located 97 km (60 mi) due east of Los Angeles (Figure A-19). The Fontana Regional Plant No. 3 is both owned and operated by the Chino Basin Municipal Water District, located nearby in Cucamonga, California. The Fontana facility was visited on April 21, 1980.

The Fontana area is basically a warm, semiarid area. The mean annual temperature is 17.4°C (63.3°F), the mean yearly precipitation is 0.32 m (12.71 in), and the mean annual Class A pan evaporation is 1.8 m (69 in).

The preapplication treatment at the Fontana plant consists of screening followed by primary clarification (Figure A-20). Primary effluent flows directly to land application, and the primary sludge is thickened, digested, and dried. The land treatment portion of the facility consists of both rapid infiltration and slow-rate systems. The rapid infiltration system is operated year-round by the plant staff, whereas the slow-rate system is used during the summer months for irrigation of a citrus grove by a nearby farmer.

The Fontana Regional Plant No. 3 was designed to treat 0.088 m^3/s (2 mgd). Current flow to the facility averages 0.127 m^3/s (2.89 mgd). The facility receives no industrial discharges. The facility has been in operation for 27 years, however, the Chino Basin Municipal Water District has been operating the plant since January 1973. Land use in the vicinity of the facility consists of industrial, agricultural, and unused steep hills to the south. There are no plans for changes at the facility.

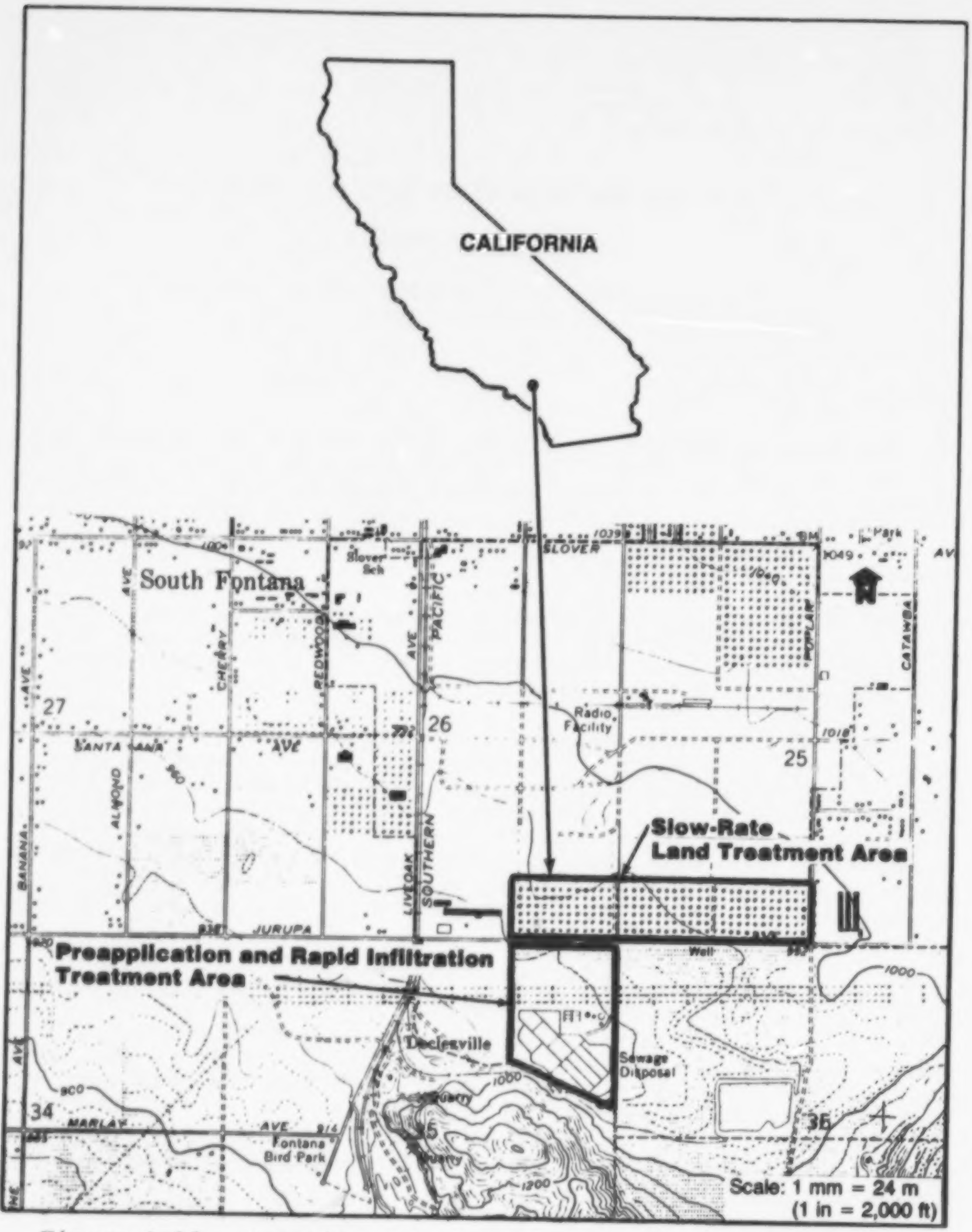

CALIFORNIA
South Fontana
Slover Sch
SLOVER
AV
Park
CHERRY
REDWOOD
AVE
PACIFIC
POPLAR
CATAWBA
27
26
25
34
35
Radio Facility
SANTA ANA
AVE
BANANA
ALMOND
LIVEOAK
SOUTHERN
JURUPA
Slow-Rate Land Treatment Area
Preapplication and Rapid Infiltration Treatment Area
Well
1000
Declezville
Sewage Disposal
Quarry
MARLAY
Fontana Bird Park
1200
900
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-19. Location map of Fontana regional plant no. 3 (# 007), Fontana, California.

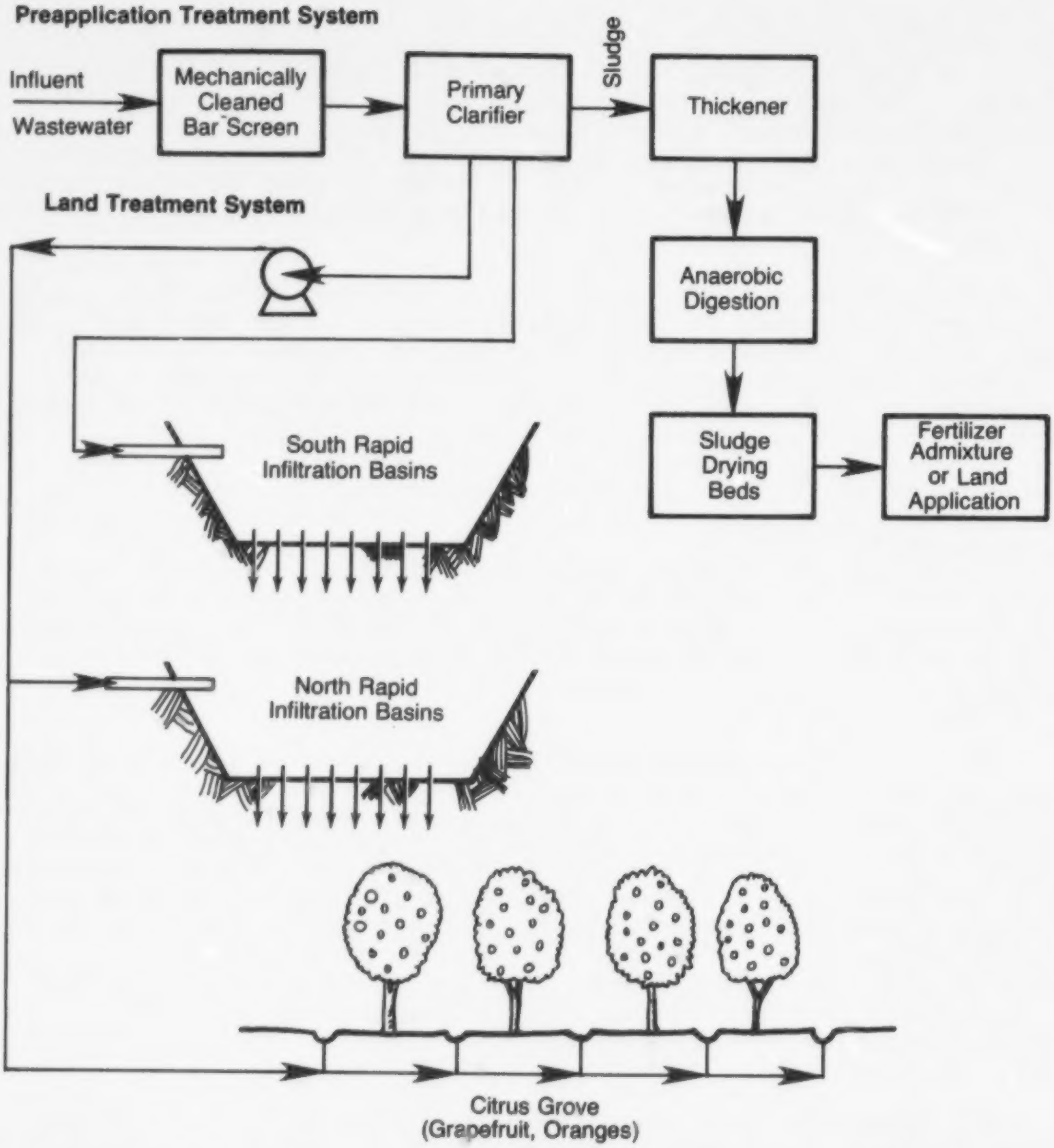

Preapplication Treatment System
Influent Wastewater
Mechanically Cleaned Bar Screen
Primary Clarifier
Sludge
Thickener
Anaerobic Digestion
Sludge Drying Beds
Fertilizer Admixture or Land Application
Land Treatment System
South Rapid Infiltration Basins
North Rapid Infiltration Basins
Citrus Grove (Grapefruit, Oranges)

Figure A-20. Process flow diagram of Fontana regional plant no. 3 (# 007), Fontana, California.

PHYSICAL FACILITIES

Influent wastewater from the collection system flows first through a mechanically-cleaned bar screen, and then to a circular primary clarifier. Screenings are removed and disposed of on-site. The primary effluent next enters the land application distribution system. Sludge from the primary clarifier is gravity thickened, and anaerobically digested in a heated single-stage digester. Digested sludge is dried on sand beds, stored, and occasionally removed by a fertilizer manufacturer for use as an admixture.

Although there is no chlorine contact tank, provisions exist for gaseous chlorine in-line addition prior to the land application system. The land application system is comprised of two different arrangements--a rapid infiltration system and a slow-rate system. The rapid infiltration system consists of 18 older south beds ranging in size from 0.05 ha (0.13 acre) to 0.71 ha (1.76 acres) with a total area of 7.78 ha (19.23 acres), and three newer north beds with approximately 6.5 ha (16 acres) total area (Figure A-21). The berms on the infiltration beds are approximately 1.2 to 1.8 m (4 to 6 ft) deep. The south beds were constructed in 1953, whereas the north beds were constructed in 1979. The wastewater flows to the south beds by gravity. All wastewater must be pumped to the north beds. An additional 6.1 to 8.1-ha (15 to 20 acre) empty field, located west of the beds, is used fairly regularly as an additional rapid infiltration bed.

The beds are interconnected by overflow pipes which are used both for overflow conditions and for filling various basins. In addition, the bed adjacent to the empty field overflows through a standpipe to the field. Under normal circumstances, a series of diversion structures with gates are used to feed the wastewater to one field or another. Two types of inlet structures are in use; a concrete pad approximately 1.8 m (6 ft) square with an approximately 0.46-m (1.5 ft) square opening in the center through which the water flows. The second type of structure is a pipe which is embedded in concrete through which the water discharges, spreads across the concrete splash pan, and onto the bed. Each bed has an access ramp for equipment entry and exit.

The slow-rate system consists of a 29.1-ha (72 acre) citrus grove located approximately 305 m (1,000 ft) north of the plant. The citrus crop includes 4.0 ha (10 acres) of oranges and 25.1 ha (62 acres) of grapefruit. All irrigation in the grove is ridge and furrow, and the wastewater is discharged through 0.64 m (18 in) high concrete standpipes with three slide discharge gates for flow control (typical citrus irrigation equipment).

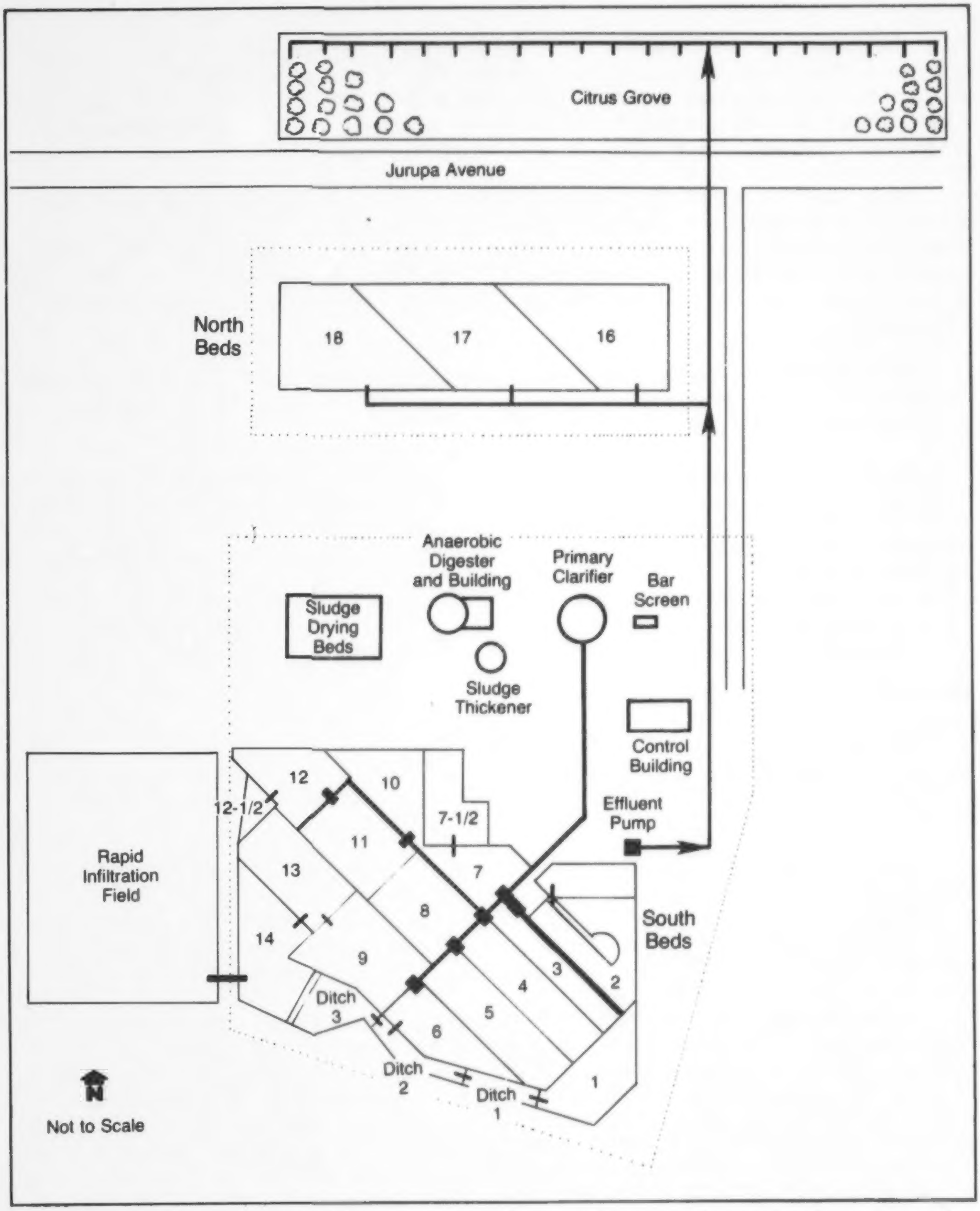

Citrus Grove
Jurupa Avenue
North Beds
18
17
16
Anaerobic Digester and Building
Primary Clarifier
Bar Screen
Sludge Drying Beds
Sludge Thickener
Control Building
Effluent Pump
Rapid Infiltration Field
12
10
12-1/2
11
7-1/2
13
7
8
14
9
3
2
4
5
6
1
Ditch 3
Ditch 2
Ditch 1
South Beds
N
Not to Scale

Figure A-21. Facility layout of Fontana regional plant no. 3 (# 007), Fontana, California.

All wastewater is pumped from the treatment plant to the citrus grove. The Fontana Regional Plant No. 3 is responsible for the distribution system to the edge of their plant property, whereas the farmer is responsible for distribution from the treatment plant perimeter to the grove.

One 22.4-kw (30 hp) centrifugal nonclog pump rated at 0.088 m^3/s (1,400 gpm) is used to pump the primary effluent to either the north infiltration beds or the citrus grove. The pump takes suction from a flooded infiltration basin which is used as a wet well. A level controller (float type) is used to cycle the pump.

The soils in both the rapid infiltration beds and the citrus grove are sandy and sandy loam soils. There are no groundwater monitoring wells in the area of the plant.

Aside from whatever storage is inherent in the rapid infiltration system, no additional storage exists. A minimum 91.4-m (300 ft) buffer zone exists between any infiltration bed and the closest neighboring property. At the citrus grove, wastewater is applied within approximately 6.1 m (20 ft) of the road. Access to the treatment plant and infiltration beds is restricted by a fence and posted signs. A few signs are visible to keep the general populace out of the citrus grove.

FACILITY OPERATIONS

Although the Fontana Regional Plant No. 3 is currently operating at 44% above design flow, it is still maintaining an acceptable degree of treatment as primary effluent BOD_5 and SS average 99 and 76 mg/L, respectively.

The primary effluent is applied to the infiltration beds continuously. The operating strategy is to apply wastewater to a bed until there is approximately 1.2 m (4 ft) of standing water in the bed. At this point, the wastewater is diverted to another bed, or just allowed to overflow into the adjacent bed.

Once filled, a bed takes approximately two to four weeks (seasonally dependent) to dry out completely. As would be expected, following wastewater application, infiltration rates decrease as a function of time due to plugging and surface sealing. Typically, after drying out, a bed is rested approximately two weeks before refilling. Depending on the visual appearance of the bed, it will either be ready for refilling or possibly taken out of service and reworked (see next section).

The slow-rate system utilized at the citrus grove is typical of that found in most groves, and irrigation practices are also typical. The farmer irrigates the trees when, by visual estimate, the top 51 mm (2 in) of soil appears dry. Typically, for a two to three-week period, 0.053 m^3/s (1.2 mgd) of wastewater is used, 24 hours per day, seven days per week. Then for the next two to three-week period, no water is used, and this cycle continues from April through October.

Based on plant operating data, the following application rates have been calculated:

	Citrus Grove	Rapid Infiltration
Hydraulic	1.6 m/yr 54.6 mm/wk	17.3 m/yr 0.33 m/wk
Organic	1,623 kg BOD_5/ha/yr	17,162 kg BOD_5/ ha/yr
Solids	1,247 kg SS/ha/yr	12,771 kg SS/ha/yr
Nutrient	472 kg NH_4-N/ha/yr	4,995 kg NH_4-N/ha/yr
	5.9 kg NO_3-N/ha/yr	43.1 kg NO_3-N/ha/yr
	410 kg T-P/ha/yr	4,335 kg T-P/ha/yr

It should be noted that the weekly hydraulic loading rate is based on a yearly average and is not the actual weekly loading rate, which cannot be calculated.

In terms of operational problems associated with the rapid infiltration beds, there is the problem of occasional odors. In addition, the sludge build-up on the surface causes decreased infiltration and necessitates cleaning. An operational problem associated with the citrus grove is the accumulation of salts (dissolved solids) in the soil. This adversely affects the growth of the fruit, and is evidenced by foliage wilting. When sufficient rainfall occurs, the salts are leached out, and this allows more efficient operation. The farmer expressed the fact that he really doesn't like using the wastewater, but he receives it free of charge as opposed to city water which he must purchase. It should be noted that the farmer actually irrigates an additional 3.2-ha (8 acre) citrus site contiguous to the wastewater-irrigated site with fresh water, as the site is bordered by a residence.

The superintendent and a chief operator run the facility with maintenance supplied by the Chino Basin maintenance department. Approximately one half of their time is spent operating and maintaining the infiltration basins.

FACILITY MAINTENANCE

Maintenance of the preapplication treatment system is adequate. However, the sludge drying beds are somewhat in a state of disrepair. The remaining equipment is adequately maintained. In terms of the land application system, the pump is new and appears well maintained. The pipes and distribution system to the south beds are adequately maintained; however, they could use some general cosmetic work. A major problem at the plant has been embankment maintenance as the dikes are not seeded. Aside from a few weeds that happen to grow on them, the dikes are natural sand and the sidewalls are, therefore, subject to considerable erosion problems. A second problem involves squirrels burrowing into the dike walls; one line had to be replaced due to squirrel burrow holes.

The intervals of both infiltration bed and open field maintenance is based on visual observation. A bed typically gets reworked once every three cycles. Reworking the bed consists of discing followed by scarifying and spring tooth raking. It is not unusual to simply disc a bed after one cycle, however. This maintenance is basically performed as the operator sees fit, and is highly dependent on what other tasks need to be done.

One maintenance problem associated with the slow-rate system involves the slide gates on the irrigation standpipes. These gates become corroded from the wastewater and must be replaced yearly. On the city water-irrigated citrus grove, the gates last many years.

OPERATION AND MAINTENANCE

A total of $160,022 was spent during fiscal year 1978-1979 for operation and maintenance of the Fontana Regional Plant No. 3. Of this total, 45% ($72,739) was associated with land application with the following breakdown:

Personnel	$34,418
Materials and supplies	2,457
Fuel and electricity	7,322
Insurance	753
Maintenance and repairs	17,739
Laboratory	3,686
Miscellaneous	1,287
Administration and general	5,077
Total	$72,739

DESIGN DEFICIENCIES

Various design deficiencies were noted during the site visit. First, some of the flow diversion structures are located so that vehicle access to various portions of the infiltration beds is impossible. In addition, the berms surrounding the beds are subject to erosion and no provisions for erosion control have been made.

Various beds are seemingly located in less permeable soils than other beds. Additional subsurface exploration prior to construction might have eliminated this problem. Another problem is that sludge accumulates in the infiltration bed utilized as a wet well, causing the float level control to stick and malfunction.

The need to pump the water to the north infiltration beds is potentially a design deficiency. In this case, however, all wastewater from the collection system flows by gravity to the plant, and it is not known whether a different arrangement would have made gravity discharge possible.

POMONA WATER RECLAMATION PLANT (# 008)

POMONA, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

The City of Pomona is located approximately 48 km (30 mi) due east of the City of Los Angeles within Los Angeles County (Figure A-22). The facility is owned and operated by the Los Angeles County Sanitation District (LACSD), and all water reuse is conducted by the City of Pomona Water Department. The facility was visited on April 22, 1980.

The climate in the Pomona area is typical of a semiarid region. The yearly average temperature is 16.7°C (62.0°F), average yearly precipitation is 0.42 m (16.45 in), and average estimated Class A pan evaporation is 1.65 m (65 in). Due to the climatic conditions, water is in great demand for general irrigation purposes such as lawns, gardens, and crops.

The Pomona Water Reclamation Plant currently treats approximately 0.35 m^3/s (8.0 mgd) of waterwater utilizing primary, secondary, and tertiary wastewater treatment (Figure A-23). The facility was designed to handle 0.44 m^3/s (10 mgd). A treatment plant has existed at the Pomona site for approximately 50 years, and wastewater irrigation has been in effect for the same number of years. During this period, there have been various additions and modifications to the facility. Of the total flow received at the Pomona plant, 0.035 m^3/s (0.8 mgd) is contributed by industrial sources.

Owing to the need for irrigation water to maintain green and healthy vegetation, irrigation is practiced heavily in the area. For this reason, most of the water from the Pomona facility is utilized in conjunction with watering lawns and gardens and some crops. The land application system would be considered a slow-rate system. As various different areas are irrigated throughout the City of Pomona, land use adjacent to the application site would be residential, commercial, industrial, institutional, and parks. There are no future plans for changes in the physical facilities at the Pomona Water Reclamation Plant, however, there are plans for expansion of the reclaimed wastewater distribution system.

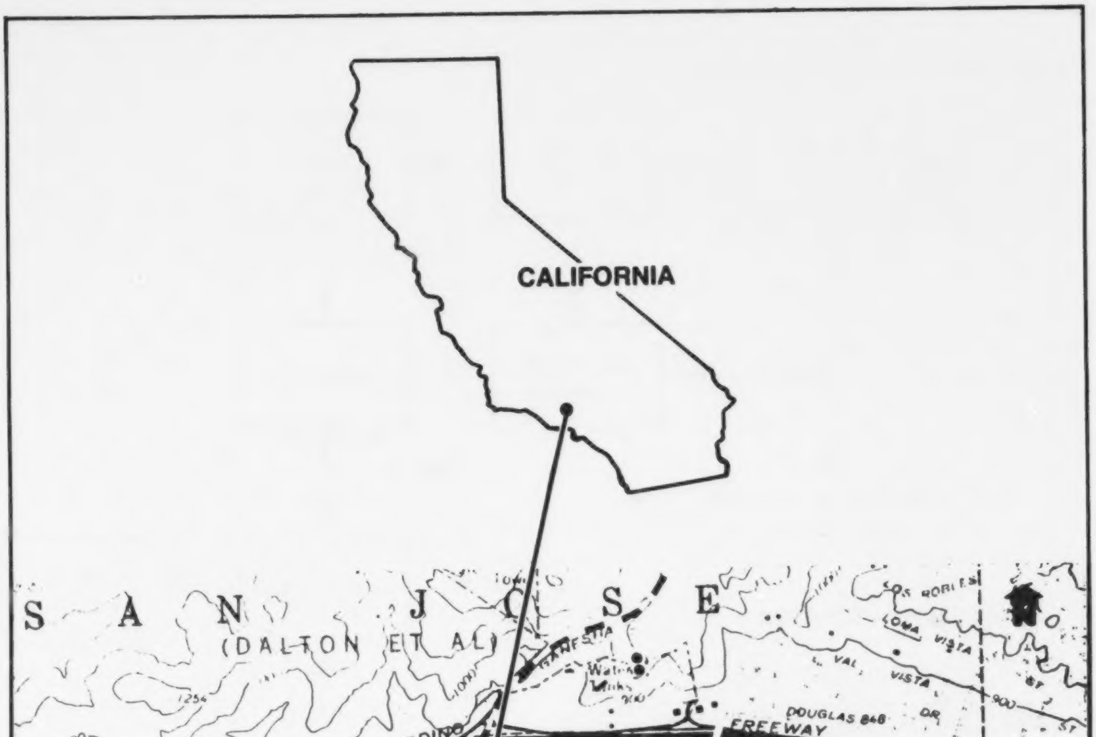

CALIFORNIA
S A N J O S E
(DALTON ET AL)
SAN BERNARDINO FREEWAY
Ganesha High Sch
CONCORD AVE
CARLTON AVE
ELWOOD
Creek
Arroyo Sch
ARROYO
Marshall Jr High Sch
LAUREL AVE
HOLT
St Joseph Sch
Trailer Park
Preapplication Treatment Area
PACIFIC
SOUTHERN
NAVAL
ORDNANCE
PLANT
Heliport
Sewage Disposal
Tower
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-22. Location map of Pomona water reclamation plant (# 008), Pomona, California.

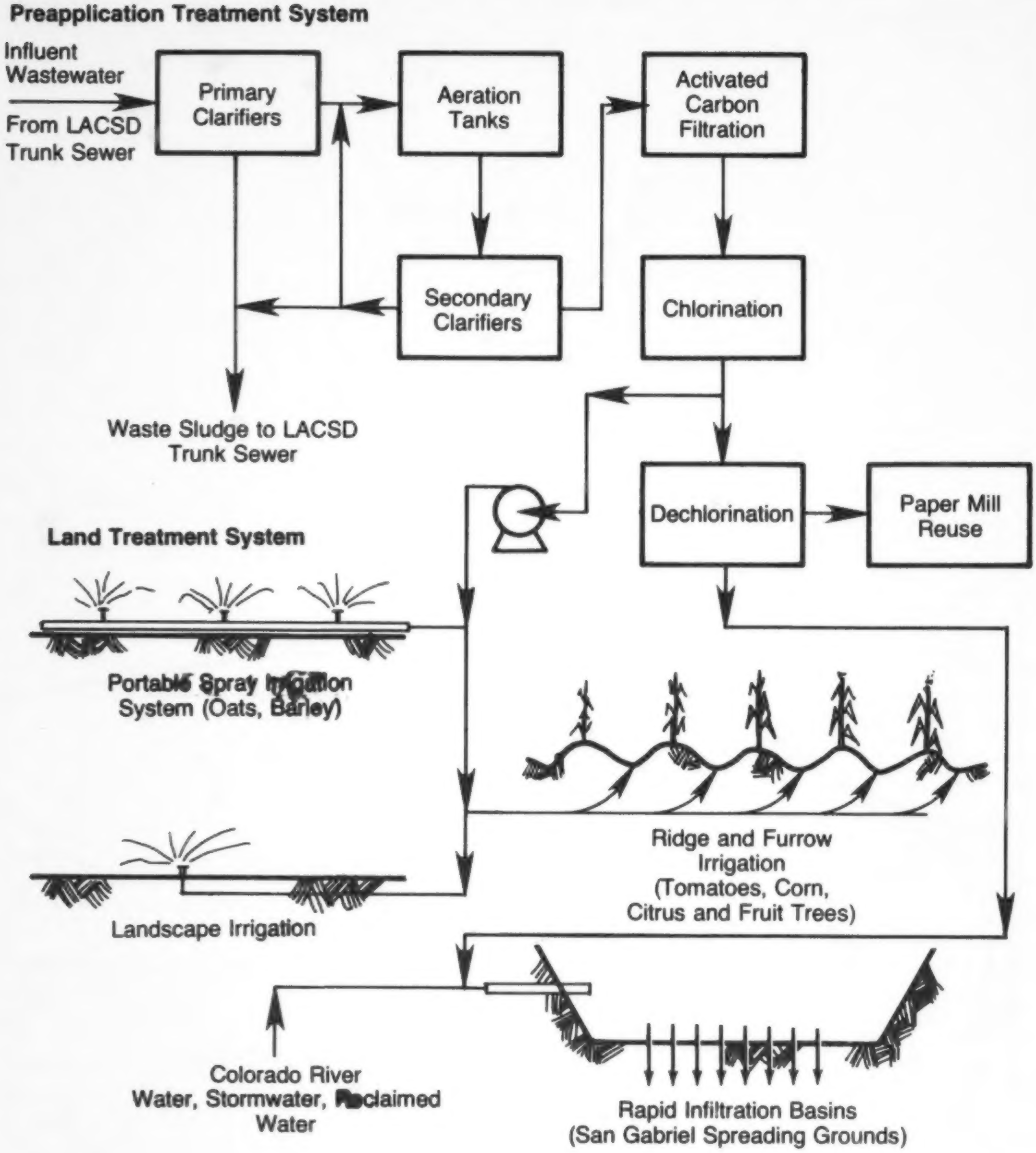

Preapplication Treatment System
Influent Wastewater
From LACSD Trunk Sewer
Primary Clarifiers
Aeration Tanks
Activated Carbon Filtration
Secondary Clarifiers
Chlorination
Waste Sludge to LACSD Trunk Sewer
Dechlorination
Paper Mill Reuse
Land Treatment System
Portable Spray Irrigation System (Oats, Barley)
Ridge and Furrow Irrigation (Tomatoes, Corn, Citrus and Fruit Trees)
Landscape Irrigation
Colorado River Water, Stormwater, Reclaimed Water
Rapid Infiltration Basins (San Gabriel Spreading Grounds)

Figure A-23. Process flow diagram of Pomona water reclamation plant (# 008), Pomona, California.

PHYSICAL FACILITIES

The Los Angeles County Sanitation District sewage system serves over four million people in 70 different cities and unincorporated areas of Los Angeles County. Most of the flow is by gravity in a large separate sewer system. A majority of the treatment plants, including the Pomona facility, are built on top of a trunk sewer. This allows the plant to pump as much wastewater as required per day from the trunk sewer. Treated wastewater is discharged to the reclaimed water system, whereas all sludge and skimmings are returned to the trunk sewer. All by-products which are returned to the sewer flow to the LACSD facility at Harbortown for subsequent treatment and disposal.

All wastewater to the Pomona Water Reclamation Plant is pumped out of the trunk sewer and into a primary settling tank. There are three primary tanks and all are covered for odor control. The air over the cover is utilized as a feed to the air compressors which supply air to the secondary aeration tanks.

At the Pomona facility, secondary treatment is accomplished utilizing three aeration tanks. Following the aeration tanks, the mixed liquor flows to one of six secondary clarifiers. The settled sludge is either returned to the aeration tanks or wasted to the trunk sewer. Effluent from the secondary clarifiers flows into an activated carbon filtration/adsorption system. There are four activated carbon filters which are operated in a constant rate varying-head mode. When backwashing is required, the filter backwash is collected in a surge tank from which point it can either be returned to the head of the secondary treatment facility or wasted to the trunk sewer. Following filtration, the wastewater is pumped to a chlorination facility consisting of two separate chlorine contact tanks. A multiple hearth furnace carbon regeneration system exists on-site.

Wastewater which is to be reused flows into a wet well after chlorination. In-line addition of sulfur dioxide is used to dechlorinate the wastewater which is not to be reused.

All reclaimed water distribution equipment is owned and operated by the City of Pomona Water Department, which, since 1966, has had an agreement with the LACSD to handle the sale of reclaimed water. The City of Pomona acts in the capacity of sales agent by promoting the use of reclaimed water, and, in addition, constructs and maintains the facilities to enable reclaimed water to be available.

The City of Pomona's reclaimed water system is divided into two zones. Zone 1 is a gravity distribution system, and zone 2 is a pressure system. There are three major users on the gravity distribution system -- the Northside Water Company, the Pacific State Hospital, and the Los Angeles County Landfill (Figure A-24). The Northside Water Company is the oldest user, and historically, has been purchasing water from the Pomona plant. The Northside Water Company sells water to various people who have used it on citrus groves and alfalfa in the past, but currently use it on small farms and for landscape irrigation. The average water usage by the Northside Water Company is 0.0066 m^3/s (0.15 mgd). The Pacific State Hospital utilizes water for landscape irrigation with an average daily water usage of 0.018 m^3/s (0.40 mgd). The Los Angeles County Landfill utilizes 227 m^3/s (0.06 mgd), and this water is utilized for dust control at the landfill.

Zone 2 which is the pressure distribution system has five major users on-line. One user, Garden State Paper Company, utilizes approximately 0.12 m^3/s (2.7 mgd) of reclaimed water for in-plant uses, and the water is not associated with land application. The other four users are Cal Poly University, Bonelli Park, the California Department of Transportation, and the Pomona Parks Department. Water usage is as follows:

Cal Poly University	0.015 m^3/s (0.35 mgd)
Bonelli Park	0.047 m^3/s (1.07 mgd)
California Department of Transportation	114 m^3/day (0.03 mgd)
Pomona Parks Department	114 m^3/day (0.03 mgd)

At all of these locations, wastewater is used for irrigation purposes. At Cal Poly University, wastewater is utilized not only for the grounds, but also for alfalfa, citrus, and various other crop irrigation. At Bonelli Park, the wastewater is used for irrigation within the Park limits and at the neighboring Mountain Meadows Golf Course. The California Department of Transportation utilizes the wastewater to irrigate the Valley Boulevard interchange of the San Bernadino Freeway (I-10). The Pomona Parks Department utilizes the water to irrigate median strips and various little parks throughout the City.

The equipment used throughout the City of Pomona is typical of irrigation equipment used elsewhere and consists of sprinklers, various types of underground spray nozzles, recessed spray nozzles, and ridge and furrow irrigation. Certain areas, Bonelli Park, for example, are controlled by timer systems. All wastewater distribution is carried out by the City of Pomona Water

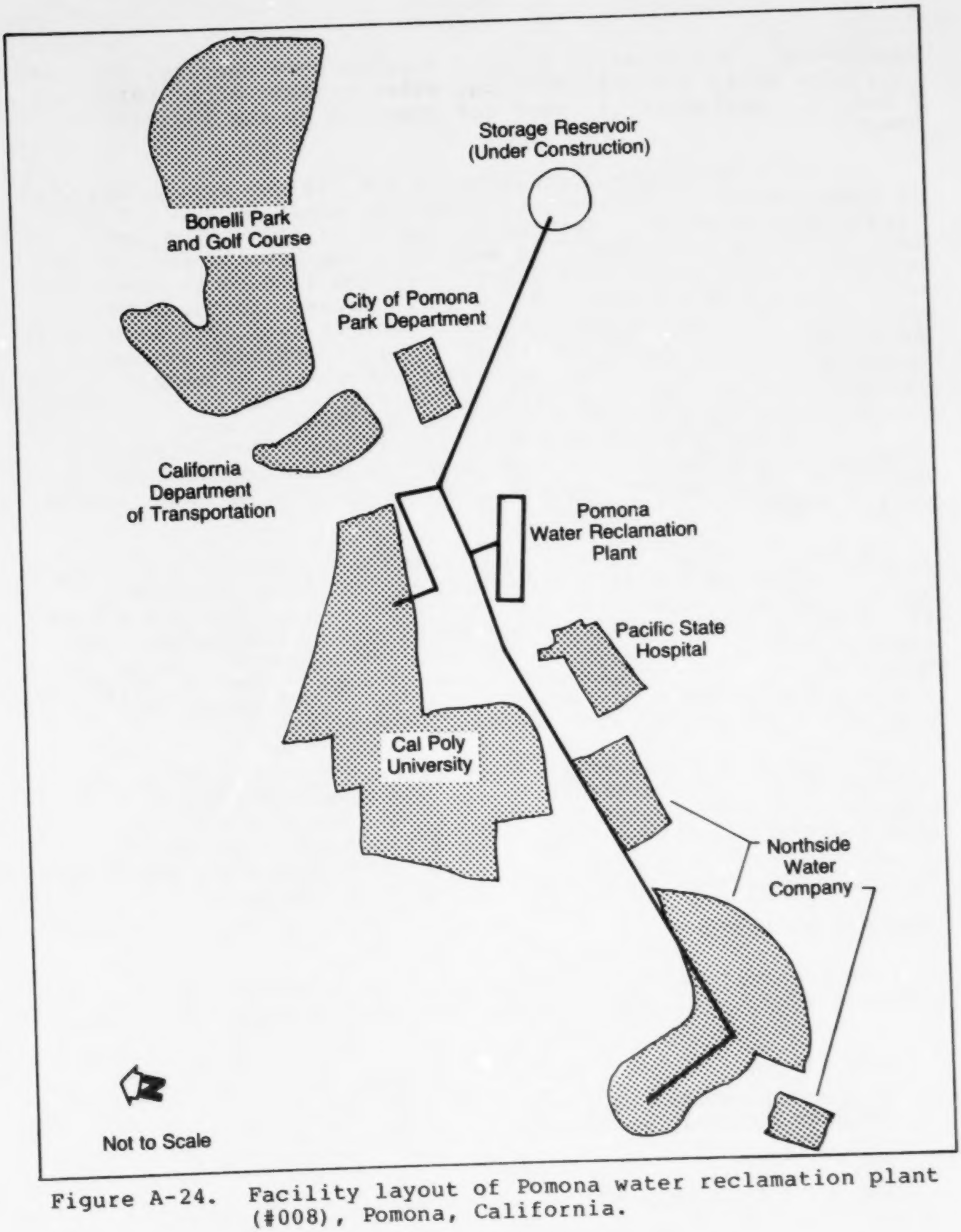

Storage Reservoir
(Under Construction)
Bonelli Park
and Golf Course
City of Pomona
Park Department
California
Department
of Transportation
Pomona
Water Reclamation
Plant
Pacific State
Hospital
Cal Poly
University
Northside
Water
Company
N
Not to Scale

Figure A-24. Facility layout of Pomona water reclamation plant (#008), Pomona, California.

Department. All water is metered through water meters, and the City owns up to and including the water meter. After this point, all equipment is owned and operated by the individual user.

In order to supply wastewater to the various users, the City of Pomona Water Department utilizes four pumps at 0.079 m^3/s (1,250 gpm) capacity. Two new 0.15-m^3/s (2,450 gpm) pumps have just been installed. In addition, one booster pump is located adjacent to Cal Poly University, and is used to boost the water up to Bonelli Park and the golf course. In terms of wastewater storage, a small storage pond is available at Bonelli Park. Currently, an 11,356-m^3 (3 mil gal) effluent storage basin is being built. The reclaimed water will be pumped to the storage pond and all flow back to the system will be by gravity. The basin is being installed so that the demand, which is higher in the evening, can be matched to the supply. Typically, all reclaimed water users also have domestic water connections for reliability in case of process upset at the Pomona Water Reclamation Plant.

There are no groundwater monitoring wells within the City, and the soils in the area vary widely. As the wastewater is used in various localities for irrigation purposes, site access is not controlled. The City of Pomona merely recommends that signs be placed at each site. Enforcement, however, is by the Health Department. There are no buffer zones prior to neighboring properties where the water is used for irrigation, and no provisions for runoff control.

It should be noted that all water that is not sold to the City of Pomona is discharged to the San Jose Creek which discharges to the San Gabriel River. As San Gabriel River water is used for groundwater recharge at the San Gabriel spreading grounds (given the proper meteorological conditions), the Pomona reclaimed water may be used for groundwater recharge.

FACILITY OPERATIONS

The preapplication treatment plant is extremely well run and produces a high quality effluent. Effluent quality is as follows:

BOD_5, mg/L	3
Suspended solids, mg/L	2
Total coliforms, no/100 ml	2
COD, mg/L	16
NH_3, mg/L	10
Chlorine residual, mg/L	3

Due to the seasonal demands for wastewater, 66% of the wastewater goes to land application during the summer months, whereas only 33% goes to land application during the winter months. During the summer, no water typically goes to San Jose Creek; during the winter 33% of the flow goes to San Jose Creek. The remaining 33% of the treated water is utilized by the Garden State Paper Company year-round.

Depending on the end use of the wastewater, the amount of water applied and the time in which the water is applied is varied. For example, someone growing crops would irrigate as they would with standard irrigation water; an individual watering a lawn would water as required. There is currently an agreement between the Los Angeles County Sanitation District and the City of Pomona that the City has all rights to reclaimed water generated at the facility. The City of Pomona buys the wastewater from the County for \$9.26/1,000 m^3 (\$11.42/acre-ft). This water is then sold back to the various end users for \$12.16/1,000 m^3 (\$15.00/acre-ft) for the gravity discharge in zone 1, and the zone 2 users pay \$48.93/1,000 m^3 (\$60.36/acre-ft). By comparison, the City of Pomona drinking water costs approximately \$100.53/1,000 m^3 (\$124.00/acre-ft). All revenues generated by the City go back into the reclamation work to cover the power utilized for pumping, amortization of capital, and new construction; no profits are generated from the sale.

Attempts are made to minimize public contact with the wastewater by irrigating public areas in the evening. In Bonelli Park, however, the hills are irrigated during the day as there is minimal chance of public contact due to the snakes and reptiles that inhabit the hills and keep the public out. The City of Pomona Water Department personnel indicated they had no particular problems with the operation of the distribution system. Approximately one hour per day is taken to check the pumps in the distribution system.

FACILITY MAINTENANCE

The Pomona Water Reclamation Plant is extremely well maintained, and it is obvious that the people working there are proud of the facility. The only above-ground equipment owned by the City of Pomona in the distribution system are the pumps and the booster pumps. These pumps appear to be well maintained, and no problems have been reported. Aside from pipes, the remainder of the distribution equipment is owned and maintained by the end users. The end users have never complained of extra maintenance due to the fact that they are using reclaimed water versus drinking water or irrigation water.

OPERATION AND MAINTENANCE COSTS

The LACSD spent a total of $579,000 per year on the operation and maintenance of the Pomona Water Reclamation Plant during calendar year 1979. This operation and maintenance cost is in part defrayed by the funds received from the sale of reclaimed water. If 100% of the reclaimed water was sold to the City, slightly over $102,000 would be collected annually. The City of Pomona Water Department estimates they annually spend $13,000 on operation and maintenance of the distribution system. This figure includes $3,000 for personnel and $10,000 for fuel and electricity.

DESIGN DEFICIENCIES

During the plant visit and subsequent conversations, it was reported that no design deficiencies existed with respect to the system.

WHITTIER NARROWS WATER RECLAMATION PLANT (# 009)

SOUTH EL MONTE, CALIFORNIA

RAPID INFILTRATION SYSTEM

GENERAL

The Whittier Narrows Water Reclamation Plant is located in El Monte, California, which is approximately 40 km (25 mi) east of the City of Los Angeles (Figure A-25). The Whittier Narrows Water Reclamation Plant is owned and operated by the Los Angeles County Sanitation District (LACSD). The land treatment portion of the system, the groundwater recharge or rapid infiltration system, is owned and operated by the Los Angeles County Flood Control District (LACFCD). The facilities were visited on April 23, 1980.

The climate in the vicinity of the Whittier Narrows facilities is mild and semiarid, with the yearly average temperature being 16.7°C (62.0°F). The yearly average precipitation is 0.42 m (16.45 in). The yearly mean annual Class A pan evaporation is estimated to be 1.65 m (65 in).

The Whittier Narrows Water Reclamation Facility was designed to handle 0.5 m^3/s (12.5 mgd). For calendar year 1979, an average daily flow of 0.70 m^3/s (16 mgd) was recorded. Approximately 50% of the flow is of commercial and industrial origin with a variety of industries contributing. The preapplication treatment at the facility consists of primary sedimentation, activated sludge, and tertiary filtration followed by chlorination and dechlorination (Figure A-26). From this point the wastewater flows to either the San Gabriel or Rio Hondo spreading grounds where it is mixed with stormwater and Colorado River water, and percolates into the soil for groundwater recharge.

The Whittier Narrows Water Reclamation Plant has been in operation for 16 years; the water has been used for groundwater recharge for the same period. The spreading grounds have been in use considerably longer. The Whittier Narrows Water Reclamation Plant is located in a basically commercial area. There are no plans for future changes at the plant.

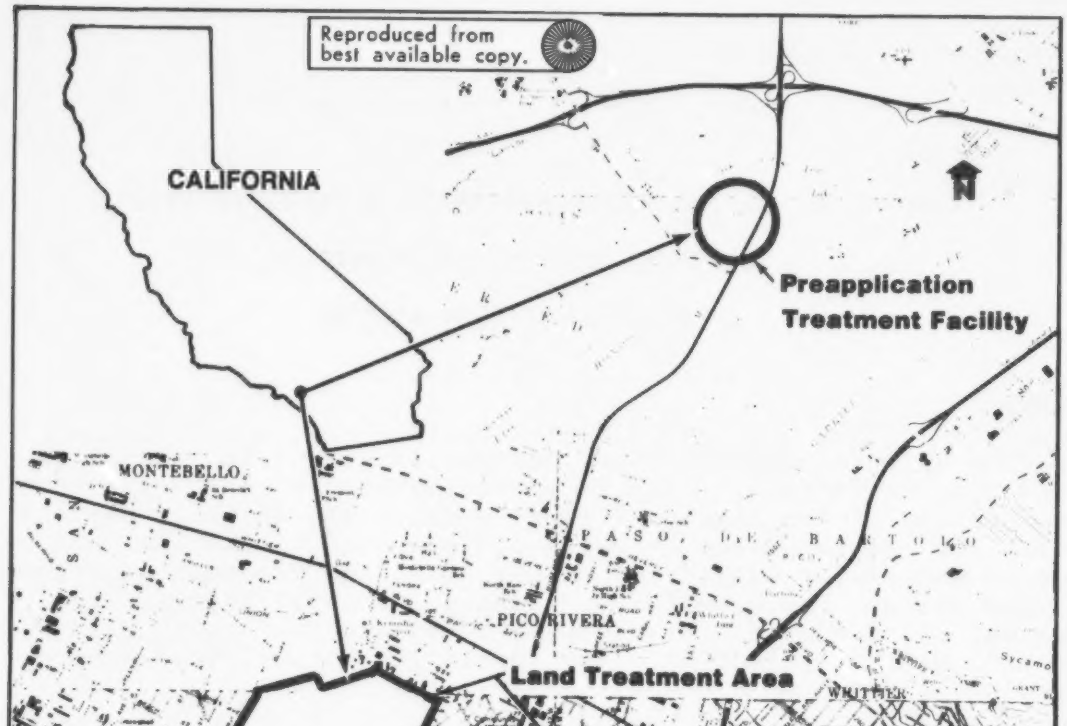

Reproduced from best available copy.
CALIFORNIA
N
Preapplication Treatment Facility
MONTEBELLO
PASO DE BARTOLO
PICO RIVERA
Land Treatment Area
WHITTIER
MONTEBELLO
West Whittier
PICO RIVERA
LOS NIETOS
Scale: 1 mm = 48 m
(1 in = 4,000 ft)

Figure A-25. Location map of Whittier Narrows water reclamation plant (# 009), El Monte, California.

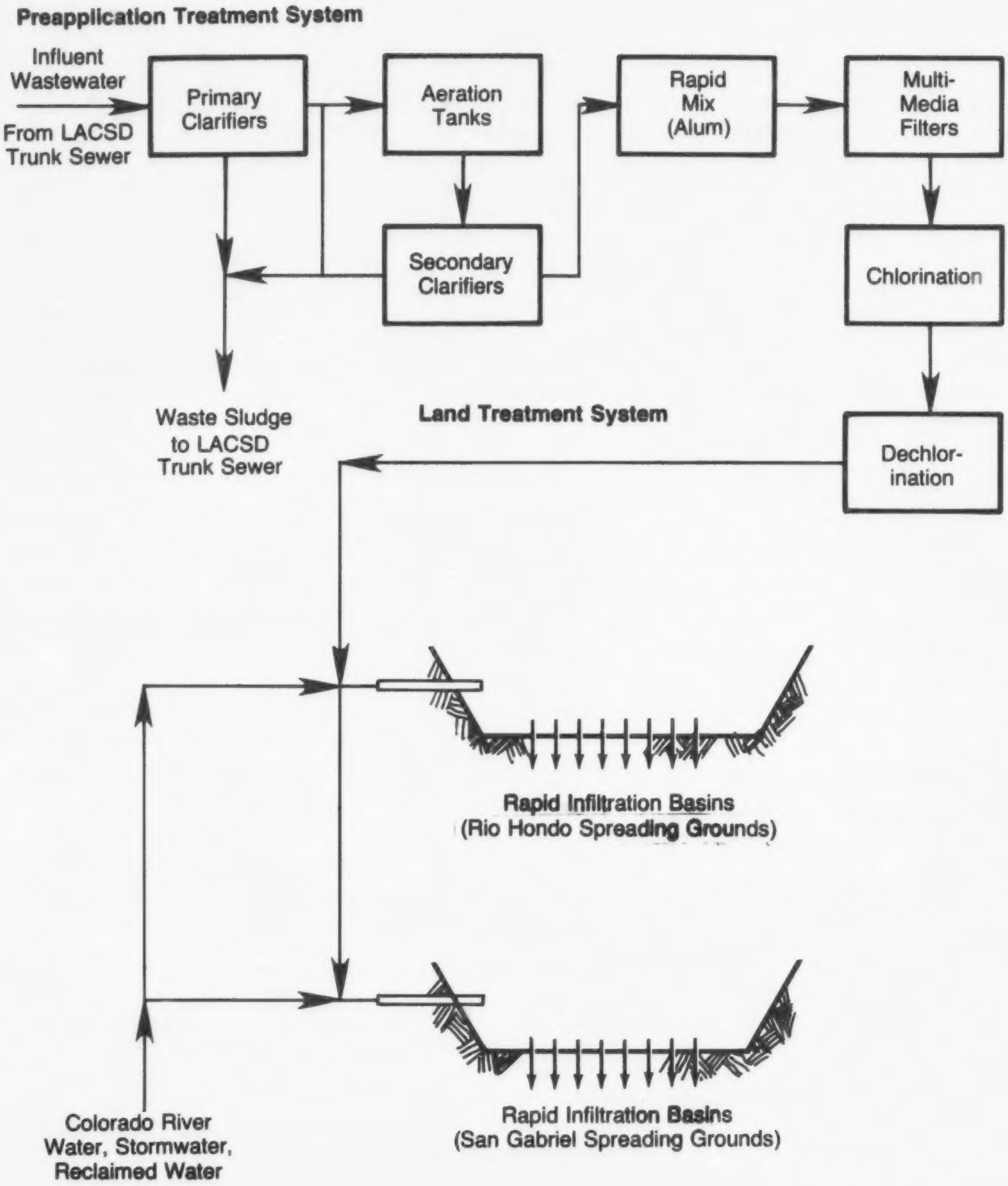

Preapplication Treatment System
Influent Wastewater
From LACSD Trunk Sewer
Primary Clarifiers
Aeration Tanks
Rapid Mix (Alum)
Multi-Media Filters
Secondary Clarifiers
Chlorination
Waste Sludge to LACSD Trunk Sewer
Land Treatment System
Dechlor-ination
Rapid Infiltration Basins (Rio Hondo Spreading Grounds)
Colorado River Water, Stormwater, Reclaimed Water
Rapid Infiltration Basins (San Gabriel Spreading Grounds)

Figure A-26. Process flow diagram of Whittier Narrows water reclamation plant (# 009), El Monte, California.

PHYSICAL FACILITIES

Preapplication treatment at the Whittier Narrows Water Reclamation Plant consists of primary, secondary, and tertiary treatment followed by disinfection. Primary treatment is carried out in two primary clarifiers which are covered for odor control. From the primary clarifiers, the wastewater next flows to one of three activated sludge aeration basins. The overflow from the aeration basins goes to six secondary clarifiers. Clarified wastewater then is conditioned by alum addition, and passes through one of six multimedia filters. The filter effluent then passes to two chlorine contact tanks. Following chlorination, the wastewater is dechlorinated using sulfur dioxide. At this point, the wastewater flows by gravity to the land application system. The wastewater treatment plant, like the Pomona Water Reclamation Plant, is located over a LACSD trunk sewer, and all sidestreams, including primary and secondary sludge and tank skimmings, are returned to the trunk sewer for treatment at a centralized facility.

The Rio Hondo and San Gabriel river system drains the entire San Gabriel Valley through a break in the topography called the Whittier Narrows. The Whittier Narrows is surrounded on both sides by hills, and a broad flood plain has been formed where the Rio Hondo and San Gabriel Rivers emerge from the Whittier Narrows. This flood plain is known as the Montebello Forebay. The Rio Hondo and San Gabriel spreading grounds are located in the Montebello Forebay (Figure A-27). The Rio Hondo spreading grounds have a total available percolation area of 182 ha (455 acres), whereas the San Gabriel River spreading grounds have a 40.4-ha (101 acres) percolation area. An additional 53.2 ha (133 acres) of spreading basins are available on the unlined portion of the San Gabriel River. The rapid infiltration basins are divided into numerous individual beds ranging in size from 1.6 to 8 ha (4 to 20 acres).

Wastewater from the Whittier Narrows Reclamation Plant flows by gravity to either of the two spreading grounds which are operated by the LACFCD. In addition, wastewater from the LACSD's San Jose Creek Water Reclamation Plant also arrives at the spreading grounds, and the potential exists for water from the Pomona Water Reclamation Plant to also reach the spreading grounds. The present practice of groundwater recharge includes dilution of the reclaimed water with imported water prior to percolation. This dilution is intended to produce groundwater with less than 10 mg/L of nitrate-nitrogen. The reclaimed water is mixed with Colorado River water, subsurface inflow, storm inflow, and local precipitation.

Water from the Whittier Narrows Water Reclamation Plant can be discharged either directly to the Rio Hondo River just

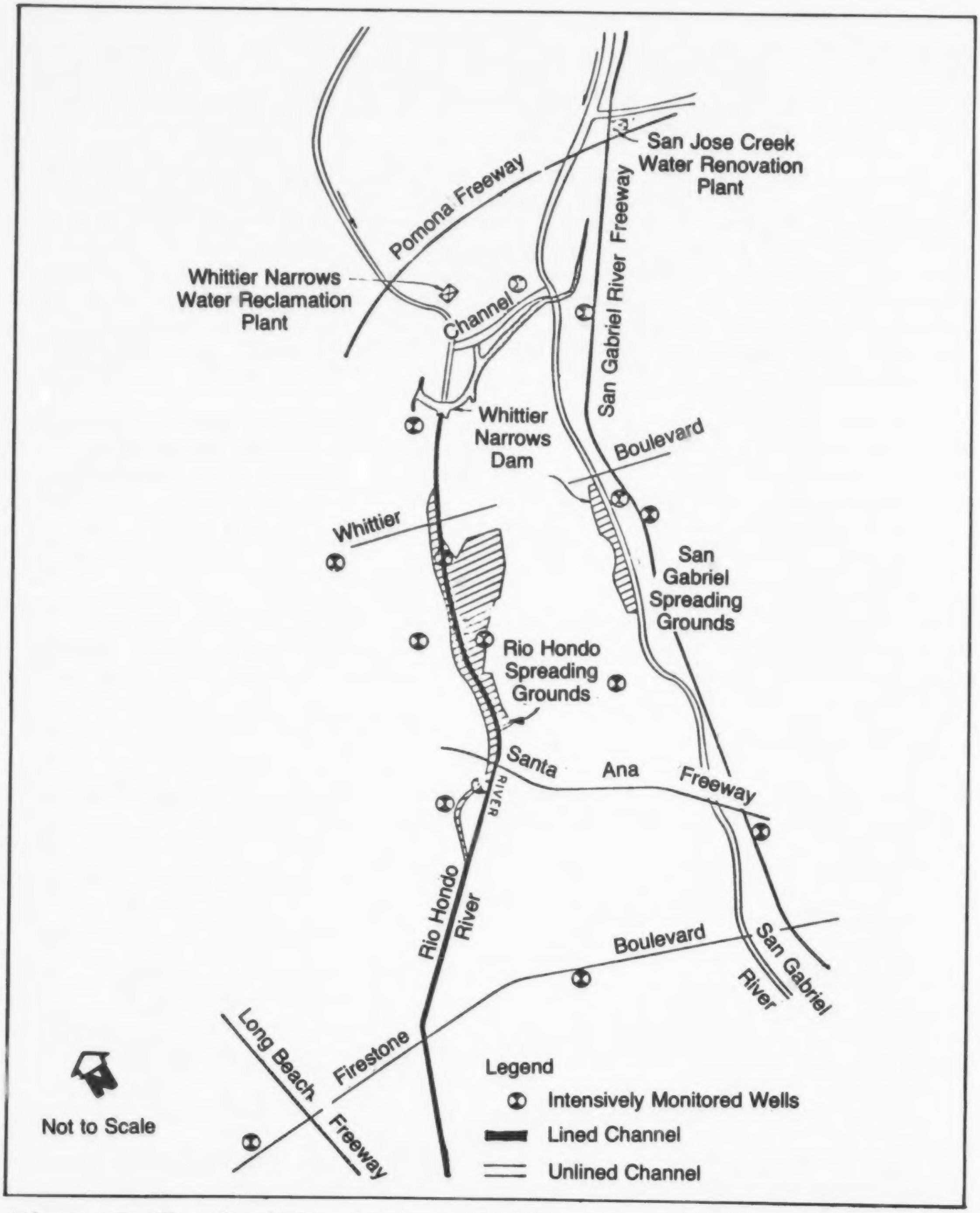

San Jose Creek
Water Renovation
Plant
Pomona Freeway
San Gabriel River Freeway
Whittier Narrows
Water Reclamation
Plant
Channel
Whittier
Narrows
Dam
Boulevard
Whittier
San
Gabriel
Spreading
Grounds
Rio Hondo
Spreading
Grounds
Santa Ana Freeway
RIVER
Rio Hondo
River
Boulevard
San Gabriel
River
Firestone
Long Beach
Freeway
Not to Scale
Legend
Intensively Monitored Wells
Lined Channel
Unlined Channel

Figure A-27. Facility layout of Whittiers Narrows water reclamation plant (# 009), El Monte, California.

upstream of the Whittier Narrows Dam, or alternatively, discharged to a channel which flows to the San Gabriel River. All flow from the Whittier Narrows facility to the rapid infiltration system is by gravity.

Due to the complex nature of the situation, organic and solids loading rates cannot be calculated. Based on information reported by Dryden and Chen (1978) for the 1975-1976 and 1976-1977 application periods, an average of 139 mil m^3 (112,500 acre-ft) of water was received at the Montebello Forebay. Considering the 289 ha (689 acres) of rapid infiltration basins, a hydraulic loading rate of 49.7 m (163 ft/yr) was calculated. The soils in the vicinity of the spreading grounds are nonhomogeneous soils consisting of both silty and fine sand.

Owing to the sensitive nature of the project, approximately 200 wells in the vicinity of the spreading grounds have been monitored. Currently, 16 wells within the Montebello Forebay are extensively monitored quarterly for major minerals, nitrogenous compounds, COD, BOD, TDS, electrical conductivity, pH, and odor; and annually for trace metals and chlorinated hydrocarbons (Dryden and Chen, 1978). A minimum buffer zone of approximately 30.5 m (100 ft) is maintained between the percolation beds and the nearest property line. Site access is controlled by posted signs and fencing. There is no surface runoff from the site, and any surface runoff which is contained is infiltrated in the soil.

FACILITY OPERATIONS

The preapplication treatment facility produces a quality effluent with the following parameters:

BOD, mg/L	2
Suspended solids, mg/L	1
NH_3, mg/L	17
COD, mg/L	27
Chlorine residual, mg/L	<0.05
Fecal coliforms, no/100 ml	<2

The spreading grounds are operated by the LACFCD. For the period 1960 to 1977, reclaimed water has represented 13.5% of the total inflow to the Montebello Forebay area, while imported and local waters represented 41.1 and 45.4%, respectively. Therefore, the reclaimed water is a minor part of the operation of the rapid infiltration spreading grounds. In terms of operation, little if any additional manpower is required due to the reclaimed water, over and above the manpower required for the imported and local waters. The LACFCD pays \$16.21/1,000 m^3 (\$20/acre-ft) for the rights to the reclaimed water.

The Rio Hondo and San Gabriel River spreading grounds are filled cyclically to maintain aerobic conditions in the upper soil strata and to control vector insects. Groups of spreading basins are rotated through a 21-day cycle, consisting of filling to a depth of 1.2 m (4 ft) for seven days, draining the basin for seven days, and then drying the basin for seven days. On this rotating basis, the capacity of the basins for recharge is approximately 757,000 m^3/day (200 mgd). On a short-term basis with all basins in operation, the capacity is approximately 2,271,000 m^3/day (600 mgd). The latter mode of operation is used during storm periods to maximize conservation of stormwater.

In terms of operational problems associated with the reclaimed water, the operators believe that greater care is required because the Whittier Narrows water keeps the forebay area wet and increases problems with insects. When this is a problem, the area is dried by switching the Whittier Narrows discharge from the Rio Hondo to the San Gabriel spreading grounds, or vice versa.

FACILITY MAINTENANCE

The Whittier Narrows Water Reclamation Plant is well maintained, and there are signs of a good preventive maintenance program. All maintenance at the Rio Hondo or San Gabriel spreading grounds is done by the LACFCD. Maintenance consists of discing the basins when required, based on the decrease in percolation rate. This is typically performed after a storm when the basins have received a large volume of silt. In addition, the basins are occasionally mowed to control the weed growth. The operational people from LACFCD feel that the wastewater does not cause plugging problems in the beds, and that no additional maintenance problems are associated with accepting reclaimed water.

OPERATION AND MAINTENANCE COSTS

A total of \$561,000 was spent during calendar year 1979 at the Whittier Narrows Water Reclamation Plant. The two major expenses associated with operation and maintenance are personnel at \$218,000, and utilities (including electric) at \$216,000 per year. There are no appreciable operation and maintenance costs associated with the rapid infiltration system as the reclaimed water (Whittier Narrows, San Jose Creek, and Pomona Water

Reclamation Plants) only accounts for 13% of the water infiltrated to the groundwater recharge system. Furthermore, the reclaimed water causes no particular operation or maintenance problems. In addition, the wastewater flows completely by gravity, and pumping is not necessary.

DESIGN DEFICIENCIES

There were no design deficiencies noted during the plant visit.

PALMDALE WATER RECLAMATION PLANT (# 010)

PALMDALE, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

Palmdale, California, is located in southern California approximately 64 km (40 mi) northeast of the City of Los Angeles, in the County of Los Angeles, on the western edge of the Mojave Desert (Figure A-28). The Palmdale Water Reclamation Plant is owned and operated by the Los Angeles County Sanitation District (LACSD). The facility was visited on April 24, 1980.

The climate in Palmdale is characterized by cool, moist winters and hot, dry summers. The yearly average temperature is 16.4°C (61.6°F), the average annual precipitation is 0.2 m (7.87 in), and the mean annual Class A pan evaporation is 1.78 m (70 in).

The Palmdale Water Reclamation Plant treats 0.08 m^3/s (1.85 mgd) of primarily domestic wastewater. No estimates of the industrial contribution are available. The preapplication treatment facilities were designed to handle 0.136 m^3/s (3.1 mgd) and have been in service 23 years.

An intermediate level of treatment is obtained at Palmdale utilizing primary clarification followed by oxidation ponds (Figure A-29). The treated wastewater then flows to holding ponds prior to being utilized by a farmer for irrigation purposes. Irrigation is carried out on an 80.9-ha (200 acre) farm utilizing a side-wheel roll spray irrigation system.

The treatment facilities are located adjacent to an agricultural area. Future plans for the facility include increasing the capacity of the effluent disposal system from 0.044 m^3/s (1 mgd) to 0.136 m^3/s (3.1 mgd) by providing additional storage capacity, and thereby increasing percolation and evaporation of wastewater.

PHYSICAL FACILITIES

Raw wastewater flows by gravity to the Palmdale Water Reclamation Plant, and is lifted to the headworks, which consist of a

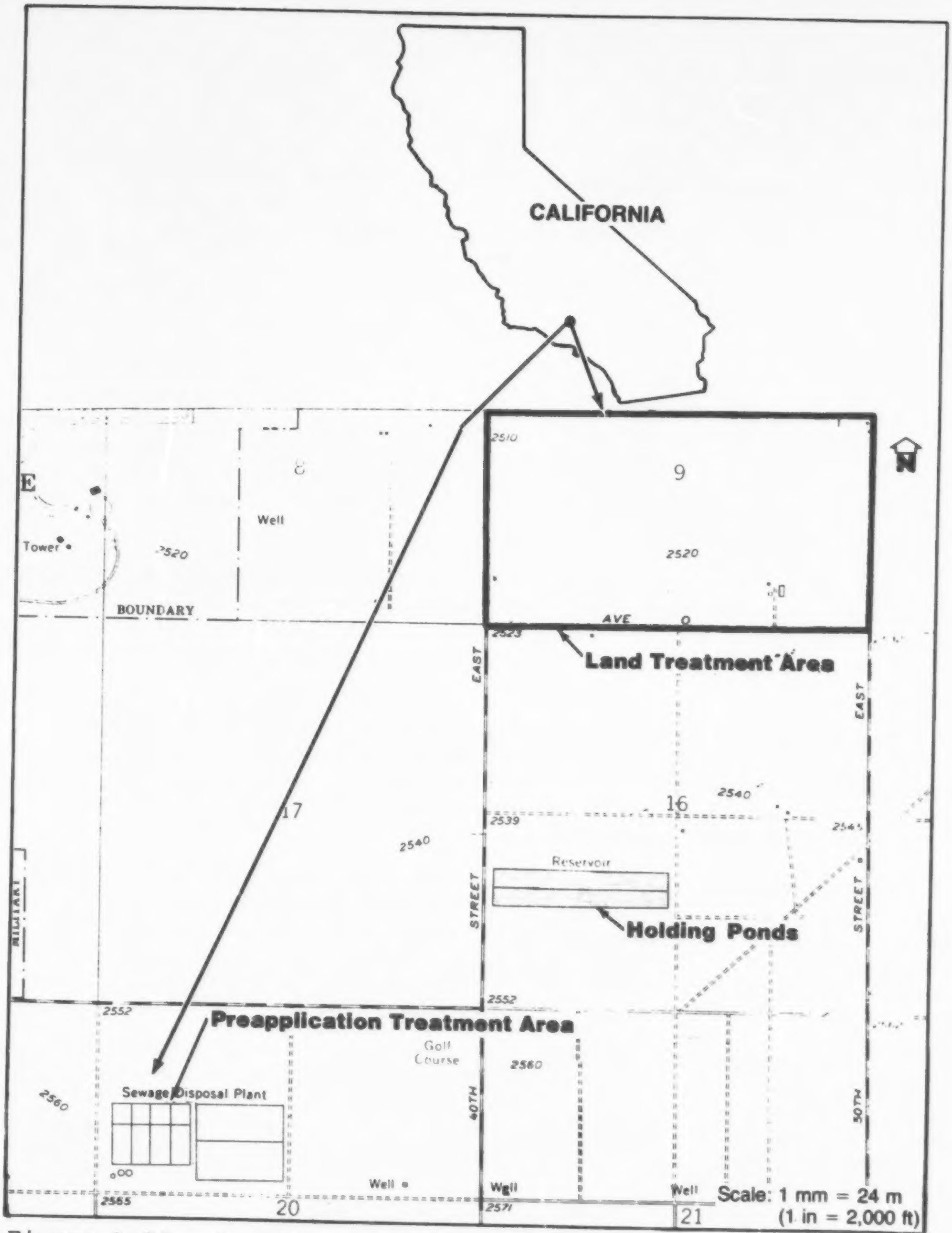

CALIFORNIA
N
9
2510
2520
AVE
8
Well
Tower
2520
BOUNDARY
E
Land Treatment Area
EAST
17
16
2540
2540
2539
2545
Reservoir
Holding Ponds
STREET
MILITARY
2552
2552
Preapplication Treatment Area
Golf Course
2560
2560
Sewage Disposal Plant
40TH
50TH
Well
Well
Well
2565
20
2571
21
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-28. Location map of Palmdale water reclamation plant (# 010), Palmdale, California.

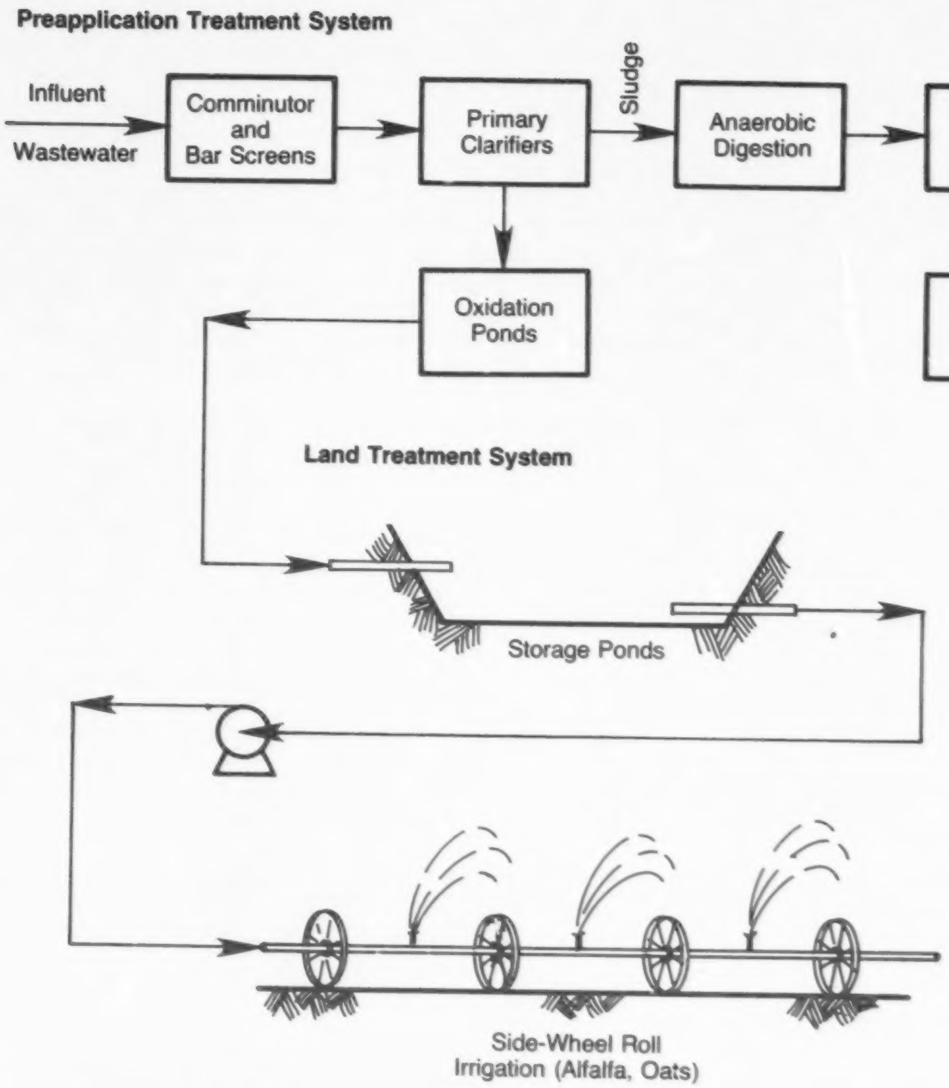

Preapplication Treatment System
Influent
Wastewater
Comminutor and Bar Screens
Primary Clarifiers
Sludge
Anaerobic Digestion
Sludge Drying Beds
Oxidation Ponds
Fertilizer Admixture
Land Treatment System
Storage Ponds
Side-Wheel Roll Irrigation (Alfalfa, Oats)

Figure A-29. Process flow diagram of Palmdale water reclamation plant (# 010), Palmdale, California.

comminutor and by-pass bar screen. The sewage next flows to one of two rectangular primary clarifiers with skimmings collected, concentrated, and pumped, along with the primary sludge, to the two-stage high-rate anaerobic digester. Digested sludge is dewatered on sand beds and stockpiled prior to removal by a fertilizer producer. Following sedimentation, the forward flow enters one of three oxidation ponds. Two of the ponds have an area of 5.7 ha (14 acres) each, and the third pond is 8.5 ha (21 acres) in size. The ponds are variable in depth, ranging from 1.2 to 2.0 m (3.8 to 6.6 ft), and are operated in parallel. Pond effluent overflows adjustable outlet weirs, and is conveyed by gravity pipe approximately 2.4 km (1.5 mi) to the storage ponds (see Figure A-30). The storage ponds cover a total area of 6.1 ha (15 acres), are 1.8 m (6 ft) deep, and contain a total of 109,780 m^3 (29 mil gal). Plans are currently under way for both short-term and long-term holding capacity expansion.

The land application system consists of an 80.9-ha (200 acre) slow-rate irrigation system. Approximately 0.044 m^3/s (1 mgd) of irrigation water is applied to the farmer's field. The LACSD owns and operates all equipment up to and including the storage ponds. From the storage ponds, a 0.305-m (12 in) gravity line approximately 1.6 km (1 mi) long conveys the reclaimed water to the farming area. Due to hydraulics, a maximum of 0.044 m^3/s can be delivered. Treated wastewater is mixed with well-water prior to irrigation. The well-water is obtained from two on-site wells, and is mixed with the treated water just prior to the booster pump. The 44.8-kw (60 hp) in-line booster pump is used to pump the water through the sprinkler irrigation system. The spray irrigation system consists of four side-wheel roll sprinklers, 416 m (1,320 ft) long with nozzles every 9.1 m (30 ft), operating at approximately 345 kPa (50 psi).

The soil at the 80.9-ha (200 acre) spray irrigation site includes sand, loam, and silt soils. There are no monitoring wells on-site, however, the water quality of the two irrigation wells is checked every six months.

FACILITY OPERATIONS

The wastewater preapplication treatment system consists of primary sedimentation followed by three oxidation ponds operated in parallel. Owing to the relative simplicity of this system, the operation of the plant is relatively stable. The water level in the three oxidation ponds is left constant. Therefore, the ponds are operated on a displacement basis, and no additional storage is provided by the oxidation ponds.

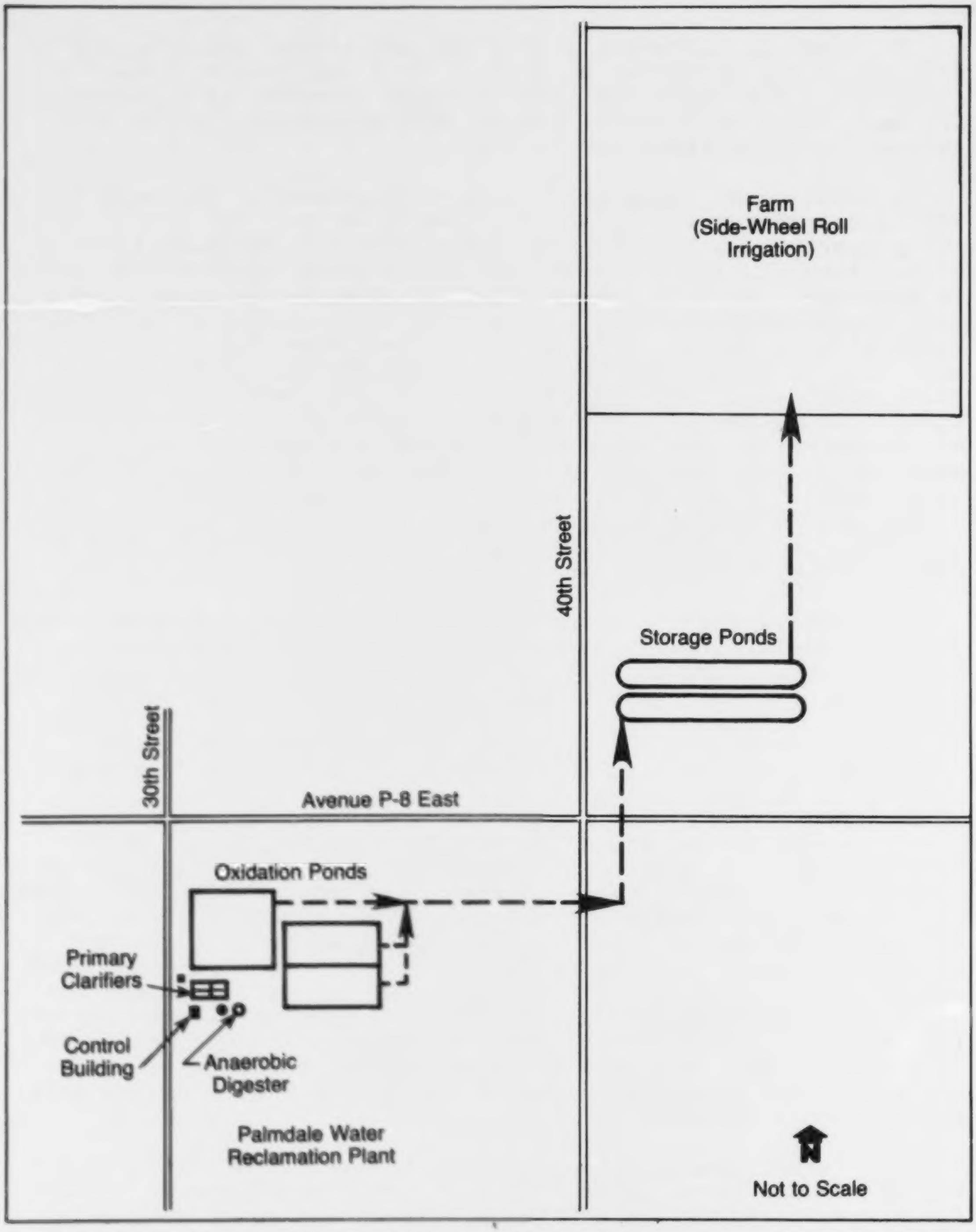

Farm
(Side-Wheel Roll Irrigation)
40th Street
Storage Ponds
30th Street
Avenue P-8 East
Oxidation Ponds
Primary Clarifiers
Control Building
Anaerobic Digester
Palmdale Water Reclamation Plant
N
Not to Scale

Figure A-30. Facility layout of Palmdale water reclamation plant (# 010), Palmdale, California.

As there is currently a need for additional storage, the operation of the oxidation ponds in a fill and draw mode may be desirable. The oxidation pond effluent contains 45 mg/L BOD_5, 120 mg/L SS, 7 mg/L NH_3-N, and 34 mg/L phosphate, and is categorized as an intermediate effluent.

A complicated situation exists with regard to the need for additional storage. The primary reason is that the farmer rents the property on a year-by-year basis from the Palmdale International Airport, a new airport for Los Angeles which may be built in Palmdale. As discussed previously, the transmission line from the storage ponds to the farm is only capable of handling 0.044 m^3/s (1 mgd). Since no one is sure when and if the airport will be built, the farmer will not invest capital to install additional capacity. Conversely, the farmer would gladly utilize more treated water since the price is low ($4.05/1,000 m^3, $5/acre-ft), and even with continuous pumping of one groundwater well and pumping the other well 50 percent of the time, only 80.9 ha (200 acres) of the available 129.5 ha (320 acres) are currently being irrigated. Therefore, the unstable condition of the lease arrangement has forced LACSD to find an alternate means of wastewater disposal.

Therefore, they have reverted to the method of disposal used at the facility prior to 1970, namely, evaporation/percolation. In order to accomplish this, an additional 38.4 ha (95 acres) of holding ponds 1.5 m (5 ft) deep are to be constructed at the current storage pond site. These ponds will be able to handle an additional 0.09 m^3/s (2.1 mgd). Arrangements have also been made with Palmdale International Airport to utilize the 0.044 m^3/s (1 mgd) if the airport is built.

Since the farmer is contractually obligated to use 0.044 m^3/s (1 mgd), the operation of his farm must be manipulated to meet the requirement. Thus, during the summer, additional water must be obtained from wells which are approximately 122 m (400 ft) deep. In the cool and relatively wet winter, the farmer typically must select one field to flood in order to dispose of excess water. During the nonwinter months, the fields are irrigated on a rigorous schedule whereby the side-wheel roll sprinkler is moved 15.2 m (50 ft) every 12 hours. The sprinklers run 24 hours per day, and each field is watered approximately once per week. The two crops grown at the site are alfalfa and oats. The crops are consumed by sheep.

The farmer operates the effluent-irrigated farm as he would any other farm in terms of fertilization. No allowance is made for wastewater-supplied nutrients. Irrespective of well-water application, and assuming 10 months of irrigation at 0.044 m^3/s (1 mgd), the land application system is loaded as follows:

Hydraulic	1.4 m/yr 33.0 mm/wk
Organic	637 kg BOD_5/ha/yr
Solids	1,699 kg SS/ha/yr
Nutrient	99.1 kg NH_3-N/ha/yr 482 kg PO_4/ha/yr

Minimal staffing is required by the operators of the Palmdale Water Reclamation Plant with regard to the land application system. On the average, only one man-hour per day is associated with going out and checking the storage ponds. The distribution system equipment is operated by the farmer.

FACILITY MAINTENANCE

The preapplication treatment facility was well maintained and the grounds extremely well kept. The storage ponds, however, suffer from two maintenance problems. First, there is a fair amount of erosion around the ponds, probably due to rainfall-induced runoff. The second problem is associated with tumbleweed which accumulates in the holding basin. Both problems necessitate additional housekeeping measures.

OPERATION AND MAINTENANCE COSTS

The Palmdale Water Reclamation Plant's annual expenditure in calendar year 1979 was $107,000. Of the total budget, 5% or $5,375 was spent on land application including $4,375 for personnel and $1,000 for mileage and rental.

DESIGN DEFICIENCIES

The inability of the effluent disposal system to handle the total design flow of the plant is the only design deficiency. Currently, short-term plans call for the immediate installation of 7,570 m^3 (2 mil gal) of additional ponds covering 1.1 ha (2.7 acres). The long-term solution calls for the addition of 38.4 ha (95 acres) of evaporation/percolation ponds holding 585,913 m^3 (155 mil gal). Considering the fact that it has taken the facility 23 years to exceed its effluent disposal capacity, this is not viewed as a major design deficiency and can be considered as proper phased construction.

IRVINE RANCH WATER DISTRICT (# 011)

IRVINE, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

Irvine, California is located in southern California approximately 72.5 km (45 mi) southeast of the City of Los Angeles (Figure A-31). The Irvine Ranch Water District owns and operates both the Michelson Reclamation Plant and the wastewater distribution system. Irvine Ranch was, in fact, one of the first dual distribution systems in the United States. The facility was visited on April 25, 1980.

The climate in the Irvine area is characterized as mild, semiarid. The average annual temperature is 16.6°C (61.9°F). The yearly rainfall averages 0.31 m (12.05 in), whereas the mean annual Class A pan evaporation is 1.52 m (60 in).

The Michelson Reclamation Plant currently produces a tertiary quality effluent by means of primary sedimentation, activated sludge, and tertiary filtration (Figure A-32). Following this, the wastewater is distributed by a dual supply system. The reclaimed wastewater is used for landscape irrigation as well as crop irrigation by the Irvine Ranch Company. The Michelson Reclamation Plant was designed to handle 0.66 m^3/s (15 mgd). Current flows at the facility average 0.35 m^3/s (8.0 mgd). The flow is basically domestic.

The preapplication treatment and the land application systems have been in operation for 11 years. Over this period, numerous expansions and upgrading of both the treatment and land application system have occurred. The land use adjacent to the land application system is widely varied, and consists of houses, parks, schools, playgrounds, and commercial areas. The future calls for increasing the size of the distribution system to allow more people to utilize reclaimed water.

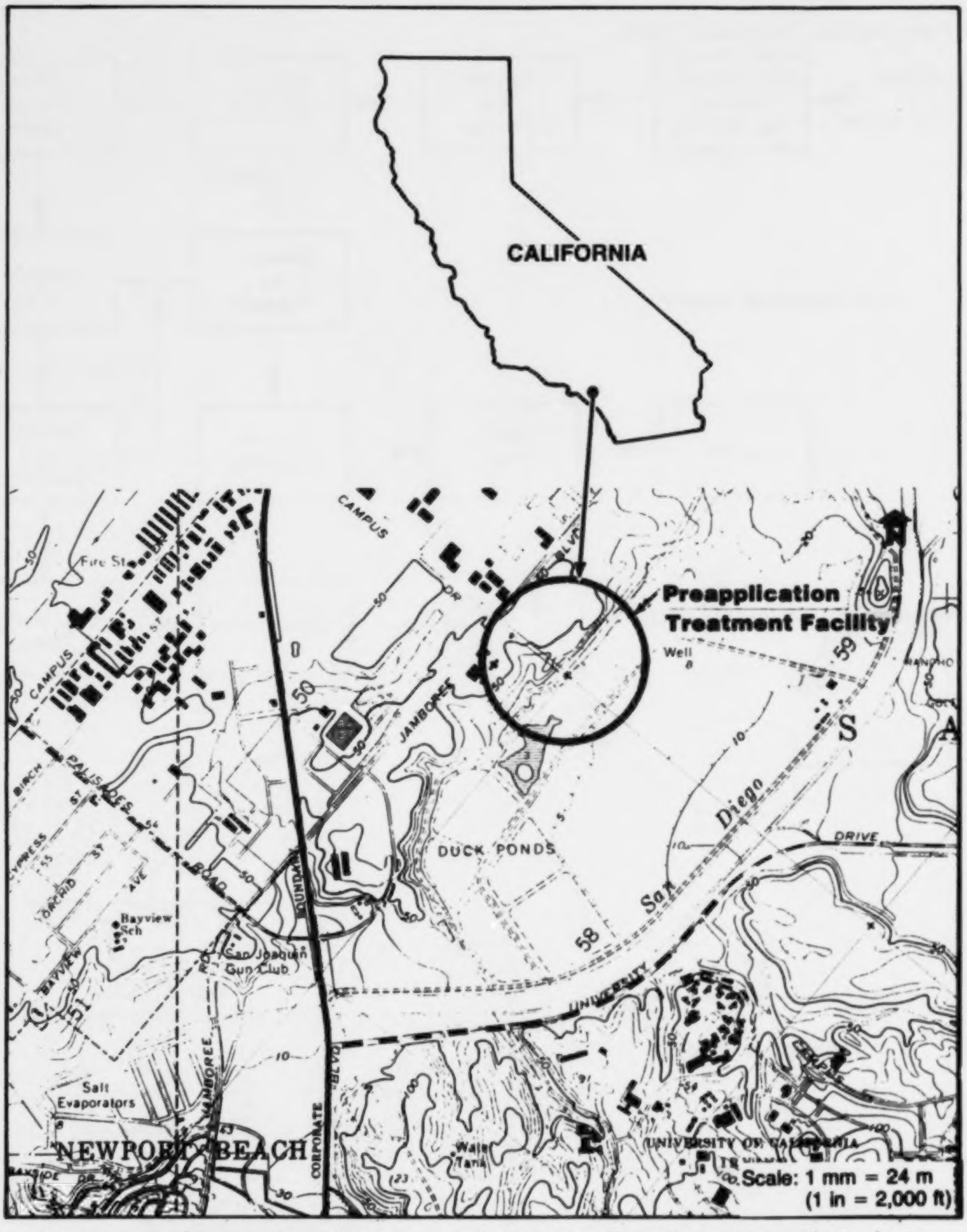

CALIFORNIA
Preapplication Treatment Facility
Well
DUCK PONDS
CAMPUS
JAMBOREE
PALISADES ROAD
San Diego
DRIVE
UNIVERSITY
Bayview Sch
San Joaquin Gun Club
Salt Evaporators
NEWPORT BEACH
CORPORATE
UNIVERSITY OF CALIFORNIA
Water Tank
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-31. Location map of Irvine Ranch water district Michelson reclamation plant (# 011), Irvine, California.

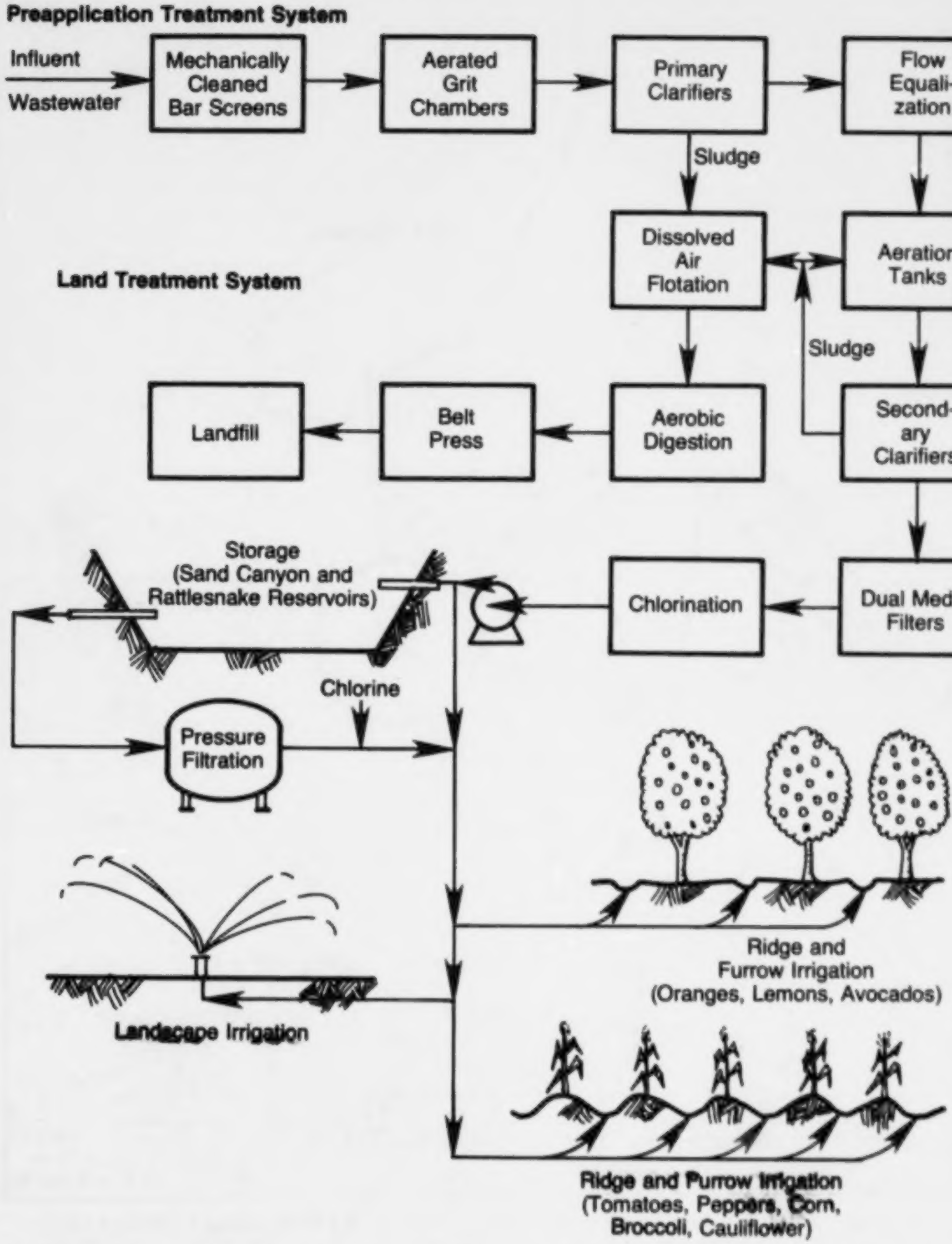

Preapplication Treatment System
Influent Wastewater
Mechanically Cleaned Bar Screens
Aerated Grit Chambers
Primary Clarifiers
Flow Equalization
Sludge
Dissolved Air Flotation
Aeration Tanks
Land Treatment System
Sludge
Landfill
Belt Press
Aerobic Digestion
Secondary Clarifiers
Storage (Sand Canyon and Rattlesnake Reservoirs)
Chlorination
Dual Media Filters
Chlorine
Pressure Filtration
Ridge and Furrow Irrigation (Oranges, Lemons, Avocados)
Landscape Irrigation
Ridge and Furrow Irrigation (Tomatoes, Peppers, Corn, Broccoli, Cauliflower)

Figure A-32. Process flow diagram of Irvine Ranch water district Michelson reclamation plant (# 011), Irvine, California.

PHYSICAL FACILITIES

Preapplication treatment at the Michelson Reclamation Plant begins with two mechanically-cleaned bar screens followed by two aerated grit chambers. The wastewater next flows to five covered primary clarifiers. Primary effluent is then pumped to one of two flow equalization basins used to supply the demand for reclaimed water during periods of low flow. After equalization, the wastewater flows to six activated sludge aeration basins followed by nine secondary clarifiers. Secondary effluent gravity flows to seven dual media filters for tertiary filtration. The filtered effluent is chlorinated prior to distribution. The solids handling consists of flotation thickening followed by aerobic digestion and dewatering on belt filter presses. Dewatered sludge is disposed of in a sanitary landfill.

Two on-site wastewater storage basins are used in case of process upset. They consist of an emergency basin capable of holding 36,340 m^3 (9.6 mil gal), and a series of manmade basins which are used in the winter as duck ponds, capable of holding 185,485 m^3 (49 mil gal). A total of 3.9 days storage is available at the design flow in these two storage basins.

There are basically two uses for the reclaimed water. The first is utilization as landscape irrigation; the second is irrigation of crops grown by the Irvine Ranch Company. The reclaimed water system itself is complicated, consisting of force mains, reservoirs, and a multiplicity of distribution equipment. Following treatment, the wastewater flows to a standpipe equipped with internal baffles to allow the effluent to go to one of two places. If the distribution system has a demand on it, the water will go directly to the irrigation network. If demand is less than production, the water will go directly to a wet well and pump station to be pumped to a reservoir. The system also has provisions for adding supplemental Metropolitan Water District (Orange County) irrigation water to the system as required. Additions of irrigation water are on a demand basis, and are not monitored.

The first storage reservoir is called Sand Canyon Reservoir, and is located approximately 4.8 km (3 mi) east of the treatment plant (Figure A-33). The reservoir holds 1,170,000 m^3 (950 acre-ft) of reclaimed water. The second major reservoir is Rattlesnake Reservoir which is located 14.5 km (9 mi) northeast of the treatment facilities, and holds 1,790,000 m^3 (1,450 acre-ft). Additional back-up storage for reclaimed water is provided by the Laguna Reservoir, and a reservoir located at the El Toro Marine Air Station.

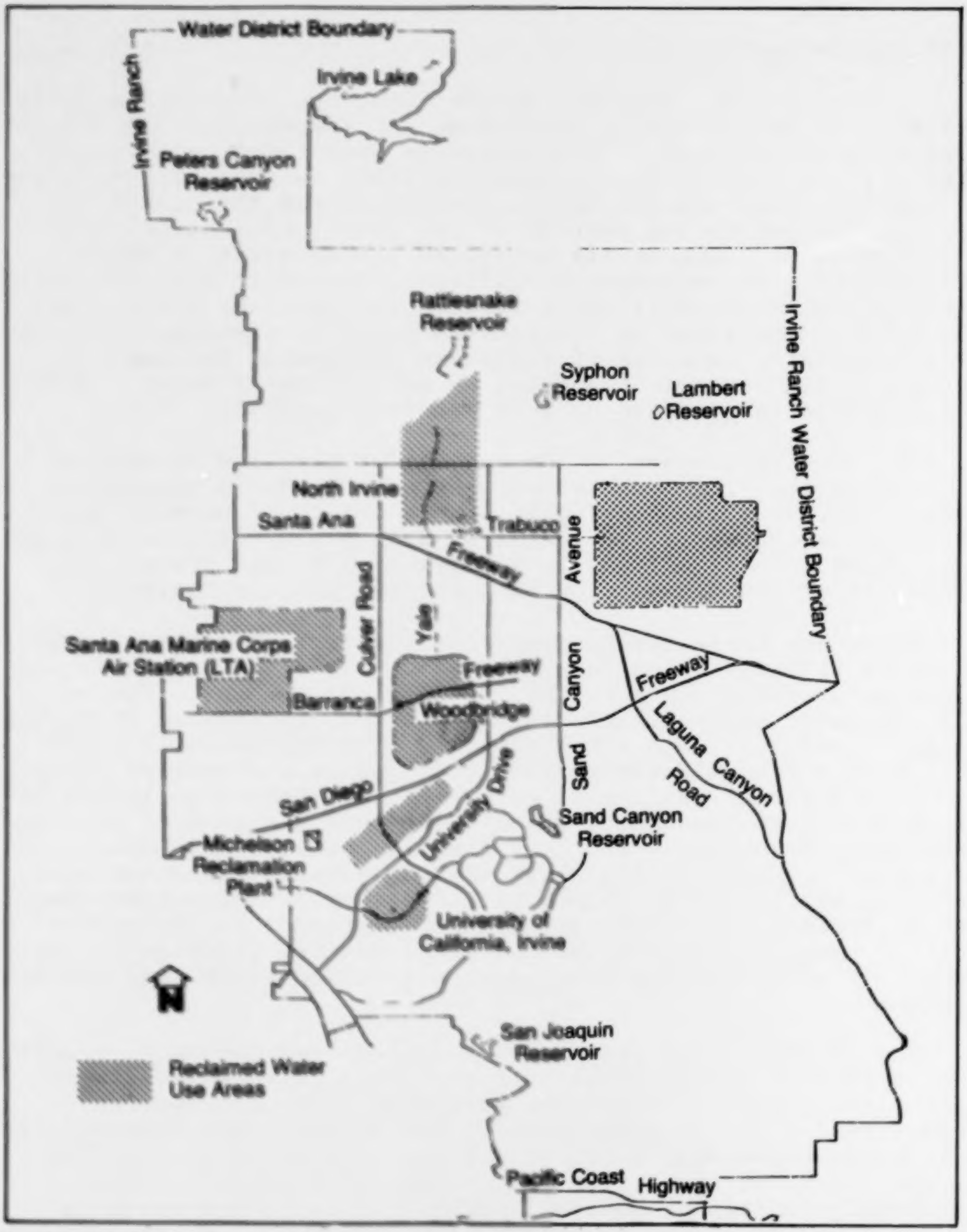

Water District Boundary
Irvine Ranch
Irvine Lake
Peters Canyon Reservoir
Irvine Ranch Water District Boundary
Rattlesnake Reservoir
Syphon Reservoir
Lambert Reservoir
North Irvine
Santa Ana
Trabuco
Freeway
Avenue
Culver Road
Yale
Santa Ana Marine Corps Air Station (LTA)
Freeway
Barranca
Woodbridge
Canyon
Freeway
Laguna Canyon Road
San Diego
University Drive
Sand
Sand Canyon Reservoir
Michelson Reclamation Plant
University of California, Irvine
N
San Joaquin Reservoir
Reclaimed Water Use Areas
Pacific Coast Highway

Figure A-33. Facility layout of Irvine Ranch water district Michelson reclamation plant (# 011), Irvine, California.

Various pumping stations in the reclaimed water distribution system are utilized to transmit the water to the right place at the right time. Pumps at the treatment plant allow for water to be pumped to either Sand Canyon or Rattlesnake Reservoir, and pumps at the reservoirs allow water to be pumped back to the system or from one reservoir to another. Due to the degradation in water quality that occurs during storage in these reservoirs due to algae growth and natural debris, the wastewater is filtered and chlorinated prior to redistribution in the system.

A dual distribution system for using reclaimed water to irrigate public land and a common green belt has been installed at Irvine Ranch. Currently, there are an estimated 80 km (50 mi) of distribution mains to carry the reclaimed water to the point of use. Pipes in the system are specially marked to insure identity. On-site control of the irrigation system is possible by utilizing specially-designed valve wells with special quick couplers. These couplers are custom items and are not available in local stores. In addition, there are special colors, as well as notices on the water system to show that it is reclaimed and not for drinking. In areas not yet served by reclaimed water, backflow preventers are installed on the dual supply system to allow domestic water to be used until the reclaimed water irrigation system can be used, at which time the backflow preventer is removed and the system connected. Currently, landscape is irrigated at housing projects, school yards, playgrounds, green belts, and the like. Where reclaimed water is sprayed on residential lawns, it is maintained by Community Association Landscape Maintenance Groups and not the individual homeowner. School grounds and playgrounds are irrigated from 9 p.m. until 6 a.m. to allow a dry-up time prior to use by children.

The second use of the reclaimed water is by the Irvine Ranch Company which utilizes the reclaimed water for irrigation purposes. Reclaimed water is used on tomatoes, peppers, corn, broccoli, cauliflower, oranges, lemons, and avocados, and all crops are irrigated by means of drip or ridge and furrow irrigation.

Due to the high degree of treatment, no attempt is made at site control during spraying of the crops or landscape. In addition, there are no buffer zones, no attempts made to control runoff, and no groundwater monitoring wells in the Irvine Ranch Water District area.

FACILITY OPERATIONS

Because of the need for a high quality effluent due to the end use of the water, a rather large operational staff is available at the Michelson Reclamation Plant. The plant is well run, as evidenced by the following effluent quality:

BOD_5, mg/L	5
Suspended solids, mg/l	2
COD, mg/L	20
PO_4, mg/L	7
Chlorine residual, mg/L	>2
Fecal coliforms, no/100 ml	0

The irrigation carried out by the Irvine Ranch is conducted in accordance with typical irrigation practices utilizing both drip and ridge and furrow irrigation. All crops are irrigated as required to insure maximum crop production. In addition, crops are fertilized without regard to any nutrients contained in the reclaimed water.

An operational problem the Irvine Company must work around is that they cannot use reclaimed water on all of their crops. Therefore, they need a dual distribution system and certain crops must be raised in certain areas. This cuts down on the flexibility of the farming operation and increases costs. If the Irvine Ranch had a choice, they would prefer to use reclaimed water only if it was economical.

The operation of landscape irrigation utilizing reclaimed water is carried out by members of the Irvine Ranch Water District in conjunction with community association groups. Operation of the irrigation system is typical, in that it is controlled by timers. The Irvine Ranch Water District maintains a staff of approximately six people who are utilized to operate and maintain the dual water supply system. Three individuals are involved with agricultural reclaimed water irrigation distribution, and three individuals are associated with landscape irrigation distribution.

The reclaimed water is sold for a variable amount depending on end-use and demand. Prices for the water vary from $32.43 to $64.86 per 1,000 m^3 ($40 to $80/acre-ft).

FACILITY MAINTENANCE

Maintenance of the Michelson Reclamation Plant is good, and all maintenance operations are carried out by Water District personnel. In addition, these personnel carry out the maintenance of the dual water supply distribution system, and it is well maintained. Maintenance of the landscape irrigation equipment is up to the community groups, and the Irvine Ranch maintains all of its irrigation equipment.

OPERATION AND MAINTENANCE COSTS

A total of $1,738,100 was spent by the Irvine Ranch Water District for operation and maintenance of the Michelson Reclamation Plant during calendar year 1979. The two major costs were personnel and utilities (fuel and electricity). The costs associated with reclaimed wastewater distribution are not known, as they are included in the Irvine Ranch Water District general irrigation budget, and cannot be easily separated out.

DESIGN DEFICIENCIES

Prior to any water being sent to either Sand Canyon or Rattlesnake Reservoir, the water is first treated to a tertiary degree. Aside from potential constraints due to regulatory agencies, this is a design deficiency as the water is degraded to such a quality after storage that it must once again be filtered and chlorinated to avoid problems such as sprinkler plugging in the distribution system. A more rational design approach would be to filter and chlorinate only that water which will be used directly, whereas water going to the reservoir should only be chlorinated following secondary treatment, and then pumped to the reservoir. This would save money and avoid duplicity in treatment.

CITY OF TULARE WATER POLLUTION CONTROL FACILITIES (# 012)

TULARE, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

The City of Tulare is located in central California approximately 72.5 km (45 mi) southeast of Fresno in the San Joaquin Valley (Figure A-34). The wastewater preapplication treatment facilities and land treatment system are owned by the City of Tulare. The operation of the land treatment system is leased out to a local farmer. The facility was visited on April 28, 1980.

The climate in the Tulare area would be considered mild, semiarid as the yearly average temperature is 17.4°C (63.4°F). The yearly average precipitation is only 0.24 m (9.53 in), whereas the yearly average Class A pan evaporation is estimated to be 2.3 m (90 in).

The Tulare wastewater treatment plant consists of an industrial wastewater (dairy) treatment facility and a domestic wastewater treatment facility, both owned and operated by the City. The wastewaters are treated separately prior to combining them in oxidation ponds. The wastewater treatment facility currently receives 0.114 m^3/s (2.6 mgd) of domestic sewage, and 0.035 m^3/s (0.8 mgd) of dairy wastewater. The plant was designed for 0.175 m^3/s (4.0 mgd) and 0.031 m^3/s (0.7 mgd) of domestic and dairy wastewater, respectively. Preapplication treatment for the domestic wastewater consists of preliminary screening and comminution, followed by primary clarification and biological treatment using either a trickling filter or an activated bio-filter (Figure A-35). The unchlorinated wastewater then flows into a series of oxidation ponds. The dairy wastewater is pretreated by means of an oil/water separator, followed by aerated lagoons. After the aerated lagoon, the dairy waste flows to the oxidation ponds and is mixed with the treated domestic wastewater. Although the effluent from the municipal biological system meets secondary treatment standards, the combined plant effluent that goes to the land application system is considered an intermediate effluent.

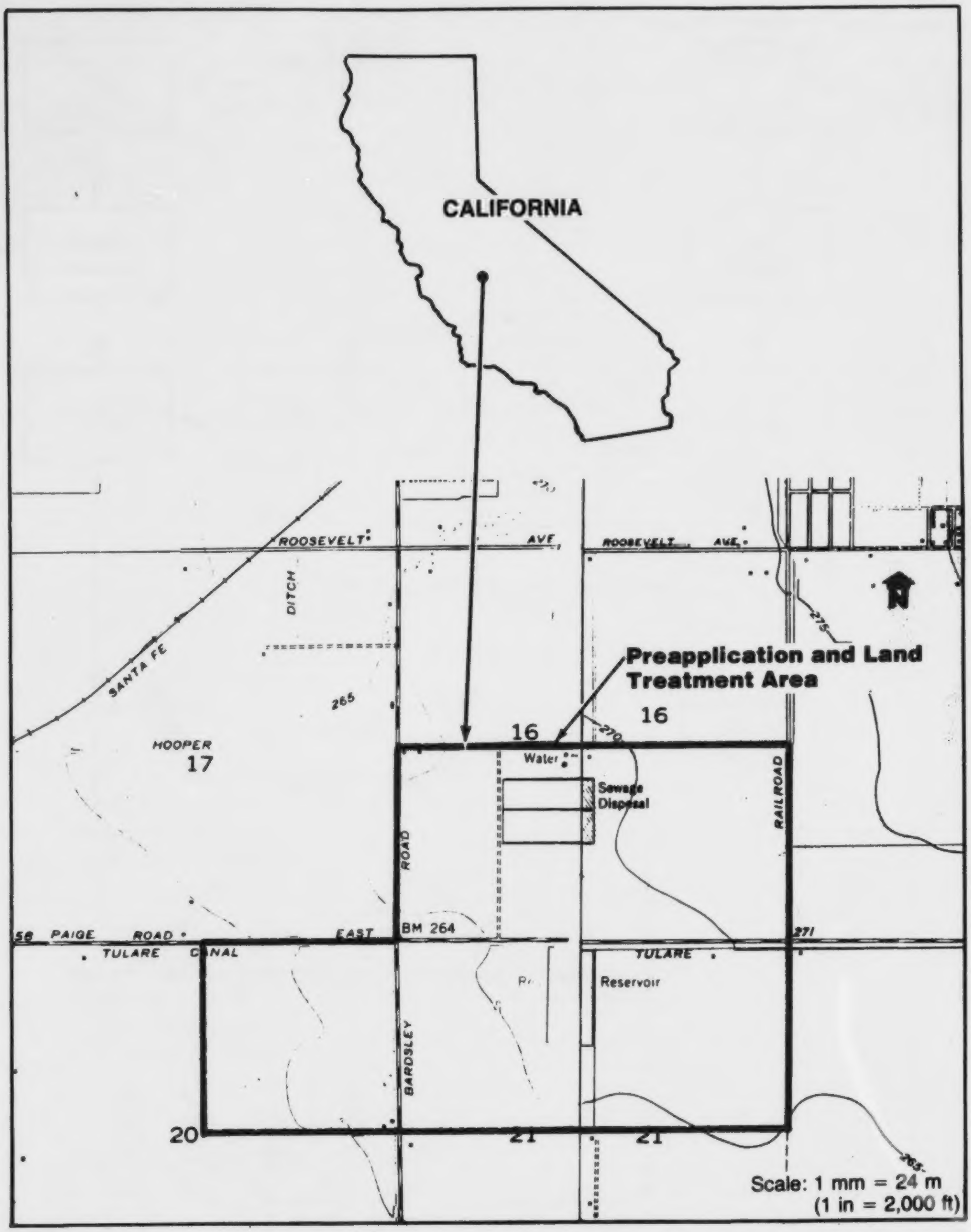

CALIFORNIA
Preapplication and Land Treatment Area
ROOSEVELT AVE
ROOSEVELT AVE
DITCH
SANTA FE
HOOPER
17
16
16
265
270
275
Water
Sewage Disposal
RAILROAD
ROAD
BARDSLEY
PAIGE ROAD
EAST
BM 264
TULARE CANAL
TULARE
Reservoir
271
20
21
21
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-34. Location map of City of Tulare water pollution control facilities (# 012), Tulare, California.

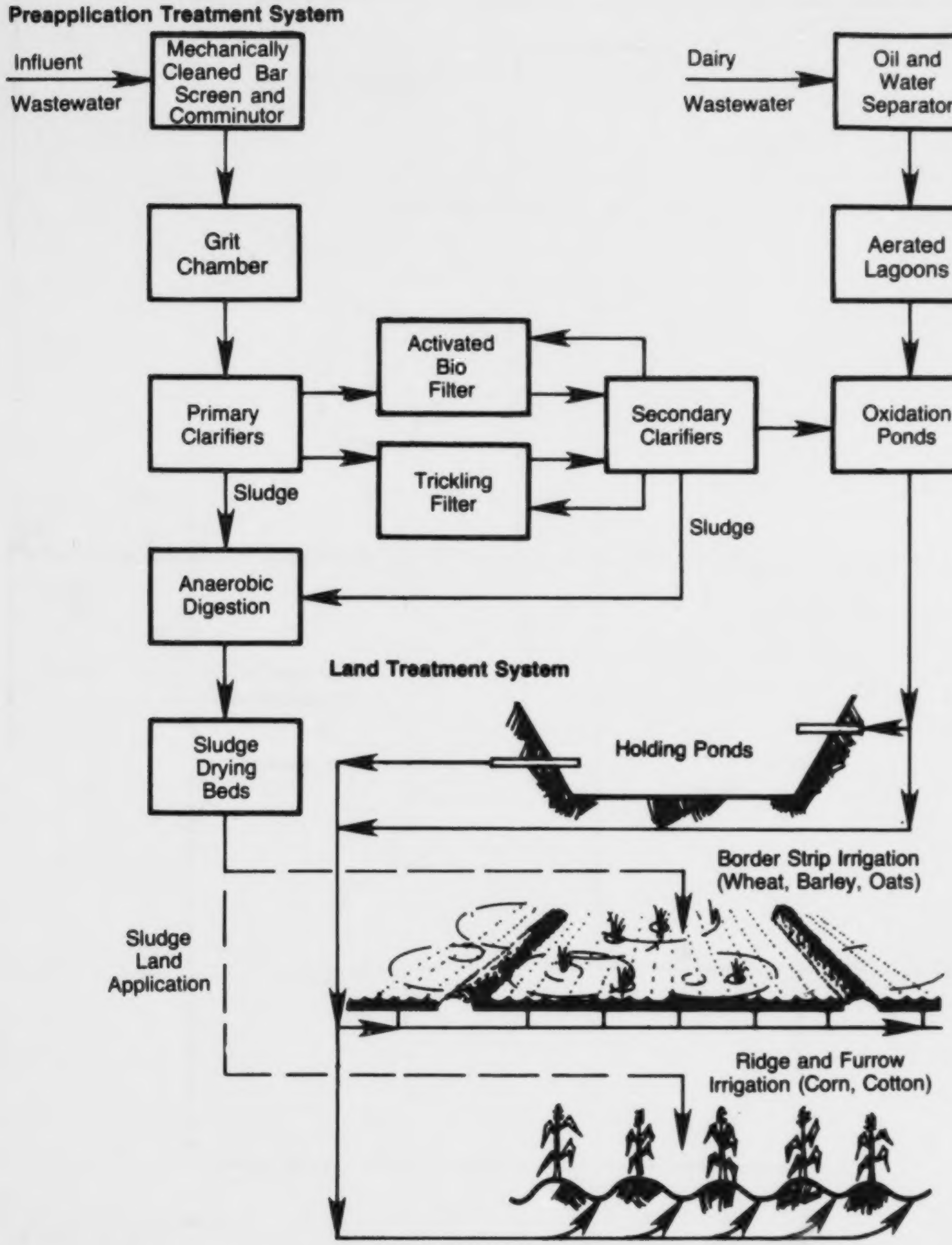

Preapplication Treatment System
Influent
Wastewater
Mechanically Cleaned Bar Screen and Comminutor
Grit Chamber
Primary Clarifiers
Activated Bio Filter
Trickling Filter
Secondary Clarifiers
Sludge
Sludge
Anaerobic Digestion
Sludge Drying Beds
Dairy
Wastewater
Oil and Water Separator
Aerated Lagoons
Oxidation Ponds
Land Treatment System
Holding Ponds
Border Strip Irrigation (Wheat, Barley, Oats)
Sludge Land Application
Ridge and Furrow Irrigation (Corn, Cotton)

Figure A-35. Process flow diagram of City of Tulare water pollution control facilities (# 012), Tulare, California.

The land treatment system consists of 205 ha (505.5 acres) of farm land which is flood or ridge and furrow irrigated. A variety of nonfood chain crops are grown on this land.

The City of Tulare has operated the land application system for over 35 years. The preapplication treatment system has been operational for 35 years and has been upgraded several times.

The land use adjacent to the land application system is basically agricultural. Future plans for the facility call for enlarging the wastewater storage capacity.

PHYSICAL FACILITIES

The preapplication treatment of domestic wastewater at the Tulare Water Pollution Control Facilities begins with preliminary treatment consisting of a mechanically-cleaned bar screen in conjunction with a rotary grinder which grinds screenings and places them back in the system. Next, a square grit chamber is used, with the grit being mechanically collected and removed. Wastewater then flows to four rectangular clarifiers.

Following primary clarification, the wastewater splits and goes to either an activated biofilter (ABF) or a trickling filter system. These two units are designed in parallel. Following the biological treatment, wastewater flows to four secondary clarifiers, two associated with each secondary train. Flow from the secondary clarifier goes to the oxidation ponds. Both waste biological sludge and primary sludge are then pumped to a two-stage high-rate anaerobic digester.

The raw dairy waste which is received goes through initial screening and oil/water separation, then is pumped to two parallel aerated lagoons located adjacent to the oxidation ponds (Figure A-36). Each lagoon is aerated by a 30-kw (40 hp) mechanical floating surface aerator. The dairy waste then overflows the lagoons into the oxidation ponds and combines with treated domestic flow. There are four oxidation ponds at the site. Each pond covers an area of 13.0 ha (32 acres) and is 1.5 m (5 ft) deep. The four ponds cover a total area of 51.8 ha (128 acres). The volume of each pond is 157,850 m^3 (41.7 mil gal) for a total storage volume of 631,400 m^3 (166.8 mil gal). At a design flow of 0.206 m^3/s (4.7 mgd), a detention time of 35.5 days is afforded by the ponds.

In addition, there are two storage ponds each covering an area of 4.9 ha (12 acres). The ponds are old oxidation ponds which were previously used for wastewater treatment, and are currently only approximately 0.46 m deep (1.5 ft). The total

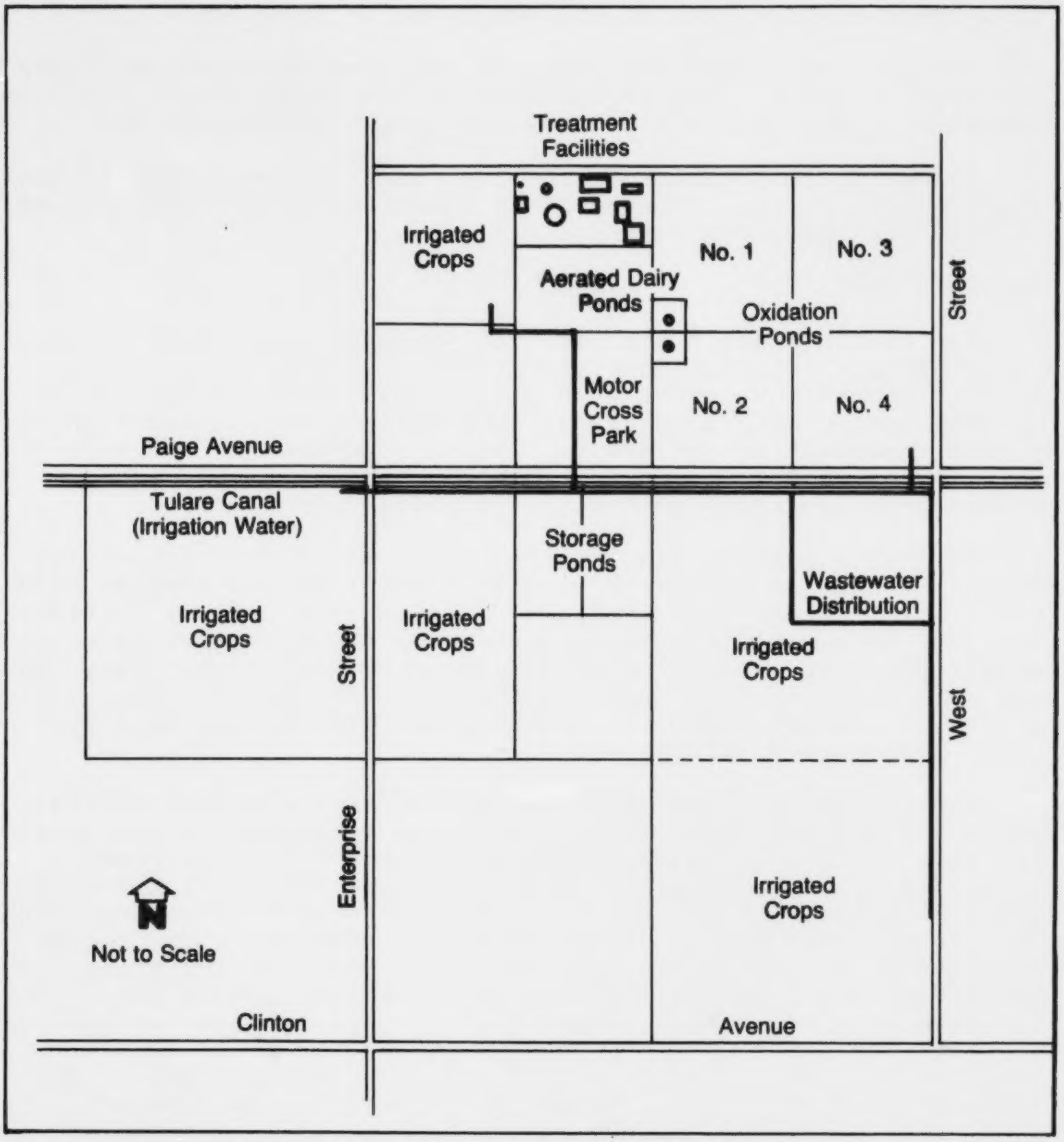

Treatment Facilities
Irrigated Crops
No. 1
No. 3
Aerated Dairy Ponds
Oxidation Ponds
Street
Motor Cross Park
No. 2
No. 4
Paige Avenue
Tulare Canal (Irrigation Water)
Storage Ponds
Wastewater Distribution
Irrigated Crops
Irrigated Crops
Street
Irrigated Crops
West
Enterprise
Irrigated Crops
N
Not to Scale
Clinton
Avenue

Figure A-36. Facility layout of City of Tulare water pollution control facilities (# 012), Tulare, California.

volume contained in both ponds is 44,660 m^3 (11.8 mil gal). Therefore, at the design flow, only 2.5 days of storage is available. As the newer oxidation ponds have a fixed standpipe withdrawal mechanism, a variable level in the ponds is not possible and these storage ponds provide the only available storage.

The slow-rate land treatment system consists of both flood and ridge and furrow irrigation of approximately 205 ha (505.5 acres). The crops grown on the site include cotton, corn, wheat, barley, and oats, none of which are used for human consumption.

The wastewater application system consists of ditch irrigation, following overflow from the oxidation ponds. For the grain crops, the border strip irrigation fields are approximately 24.4 m (80 ft) wide by 403 m (1/4 mi) long. Flow into the border strips is controlled by hand-placed irrigation gates. These gates are portable and are inserted into the ditch to control the direction of wastewater flow. Row crops are grown on ridges, and the furrows are irrigated utilizing aluminum siphon pipes which siphon the water from the irrigation ditch into the furrows. Aside from the total gravity flow of the system, there is one pump located on-site. The pump is utilized to pump water from one set of irrigation fields to another, and is used infrequently. The pump is owned and maintained by the City of Tulare, and operated by the farmer.

The areas that are irrigated consist of both sand and loam soils.

There are no groundwater monitoring wells associated with the land treatment system. The fields are operated like any other irrigation system, and there are no buffer zones between the fields and neighboring property. Site access is controlled mainly by signs which say the site is irrigated with treated wastewater. However, there are no attempts to keep people off the site. Stormwater runoff from the site does not appear to be a problem as it can be contained within the furrows of the ridge and furrow system and within the border strips.

FACILITY OPERATIONS

The preapplication treatment system is well operated, and the effluent from the combined trickling filter and activated biofilter plant averages 28 and 25 mg/L BOD_5 and suspended solids, respectively. It should be noted that since the time the ABF was started up, the operators of the Tulare wastewater treatment plant have not been happy with the system. The system is not a normal ABF in that there is no aeration tank for the solids following the bio-tower. Due to operational dislikes and difficulties, the tower is currently operated as a packed tower trickling filter, and no attempt is made at recycling effluent or sludge to the tower.

The operational problem at the facility appears to be with the industrial plant (which treats the dairy wastewater) which is severely overloaded both organically and hydraulically. The plant was designed for an organic loading of 1,400 mg/L BOD_5, yet current influent BOD_5 has been averaging 2,344 mg/L. The daily average flow to the industrial treatment facilities is 0.053 m^3/s (1.2 mgd), 71% over the design flow. Because of these problems, there is little or no biological activity in the aerated ponds. Therefore, when the dairy effluent is discharged into the oxidation ponds, it causes the ponds to also be overloaded, and substantially reduces the degree of treatment. The final oxidation pond effluent contains the following characteristics:

BOD_5, mg/L	98
Suspended solids, mg/L	177
Conductivity, mmhos	853
NH_3, mg/L	24
pH	7.6

The land treatment system is operated similar to any farm, and during the summer months crops are irrigated on a typical farm irrigation schedule. For example, corn is irrigated every 10 days and cotton every two weeks. The farm operation is carried out by the farmer as he plants, cares for, and fertilizes the fields. Fertilizer addition is typical of that on neighboring plots, and nitrogen and phosphorus are added.

The farmer's major operational problem is that he must irrigate more frequently than he cares to, particularly during the winter months, as there is minimal storage at the site and he has to dispose of the water as part of his contractual agreement. The agreement with the City of Tulare states that 25% of the farmer's receipts from the sale of any crops grown on-site must be turned over to the City.

In terms of staffing, the City of Tulare spends very little on labor associated with land treatment. The only staffing requirements are for weeding and erosion control around the oxidation ponds, and these ponds are primarily associated with waste treatment.

Based on plant operating records, excluding evaporation from the ponds, the application rates at the land treatment site are as follows:

Hydraulic	2.30 m/yr 43.2 mm/wk
Organic	2,253 kg BOD_5/ha/yr
Solids	4,070 kg SS/ha/yr
Nutrient	454 kg NH_3-N/ha/yr

FACILITY MAINTENANCE

The overall maintenance at the pretreatment facilities was good. There is one full-time maintenance man. There were some erosion problems around the oxidation pond which are due to the lack of embankment protection.

There is little or no maintenance associated with the land treatment system. All maintenance, with the exception of the one wastewater pump which is maintained by the City of Tulare, is performed by the farmer who contracts for the land.

OPERATION AND MAINTENANCE COSTS

The City of Tulare spends a total of $664,500 annually on operation and maintenance of the preapplication treatment facility. Of this total, approximately $2,180 or 0.3% is spent on the labor utilized on the land treatment system. There are no power costs associated with land treatment as the one transfer pump is used so infrequently.

DESIGN DEFICIENCIES

The first design deficiency noted was the inability to employ parallel and/or series operation of the four oxidation ponds. The ponds can only be operated as two trains in parallel. Better treatment might be possible if the four ponds could be operated in series. In addition, the aerated lagoons can only be operated in parallel.

The second and third design deficiencies are somewhat related. The second being that there is insufficient effluent storage volume to allow the farmer to maximize crop production. As discussed earlier, there is capacity for only 2.5 days of effluent storage in the storage ponds. These ponds are to be refurbished and dredged soon, thereby increasing their depth. The storage capacity could also be increased if the oxidation ponds could be operated in a varying depth mode. Currently there is a fixed standpipe, and the pond depth cannot be varied. The final design deficiency occurs because there is no embankment protection to minimize wind-induced erosion at the waterline of the oxidation ponds.

One additional potential deficiency involves the dairy wastewater treatment facility, and its inability to adequately treat the wastewater. This causes a subsequent quality degradation of the final effluent.

CITY OF KERMAN WASTEWATER TREATMENT PLANT (# 013)

KERMAN, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

The City of Kerman, California is located in central California in the San Joaquin Valley approximately 24 km (15 mi) due east of Fresno (Figure A-37). The preapplication treatment facility is owned and operated by the City of Kerman. The majority of the land treatment system is owned, and the total land treatment system is operated by a private farmer, however. The facility was visited on April 29, 1980.

Kerman, California has a mild, semiarid climate, and the yearly average temperature is 16.8°C (62.3°F). The average annual rainfall is 0.26 m (10.24 in), whereas the mean annual Class A pan evaporation is estimated to be 2.2 m (90 in).

The Kerman preapplication treatment facility consists of preliminary treatment followed by an activated sludge system (Figure A-38). Following the activated sludge system, the wastewater flows to a combination oxidation/holding pond. The slow-rate land treatment system consists of an 87.8-ha (217 acre) site on which cotton, almonds, barley, alfalfa, and sugar beets are grown. All irrigation is performed utilizing siphon tubes and ridge and furrow irrigation.

The wastewater treatment facility was designed to handle 0.018 m^3/s (0.42 mgd). Currently, the plant is receiving 0.023 m^3/s (0.52 mgd), and therefore is hydraulically overloaded by 24 percent. Of the flow received at the facility, 100 percent is of domestic origin.

The Kerman preapplication treatment facility and the slow-rate irrigation system have been in operation for approximately four years. The plant is constructed in basically an agricultural area. There are currently no plans for changes or modifications to either the land treatment system or the wastewater treatment facilities.

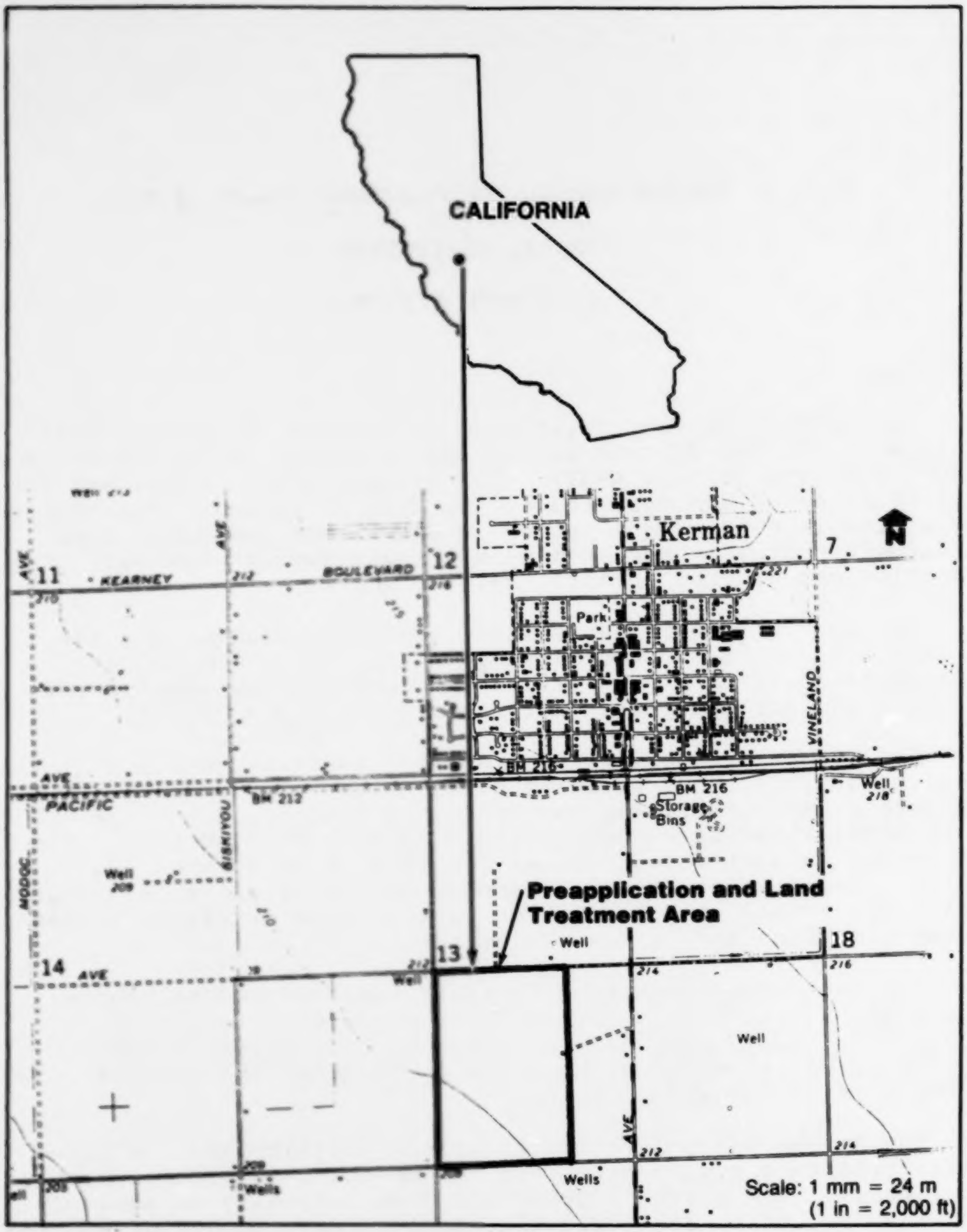

CALIFORNIA
Kerman
N
7
11
KEARNEY
212
BOULEVARD
12
216
221
Park
VINELAND
AVE
PACIFIC
BM 216
BM 212
BM 216
Storage Bins
Well
218
MODOC
AVE
SISKIYOU
AVE
Well
209
Preapplication and Land Treatment Area
Well
18
13
14 AVE
212
214
216
Well
AVE
212
214
Wells
Wells
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-37. Location map of City of Kerman wastewater treatment plant (# 013), Kerman, California.

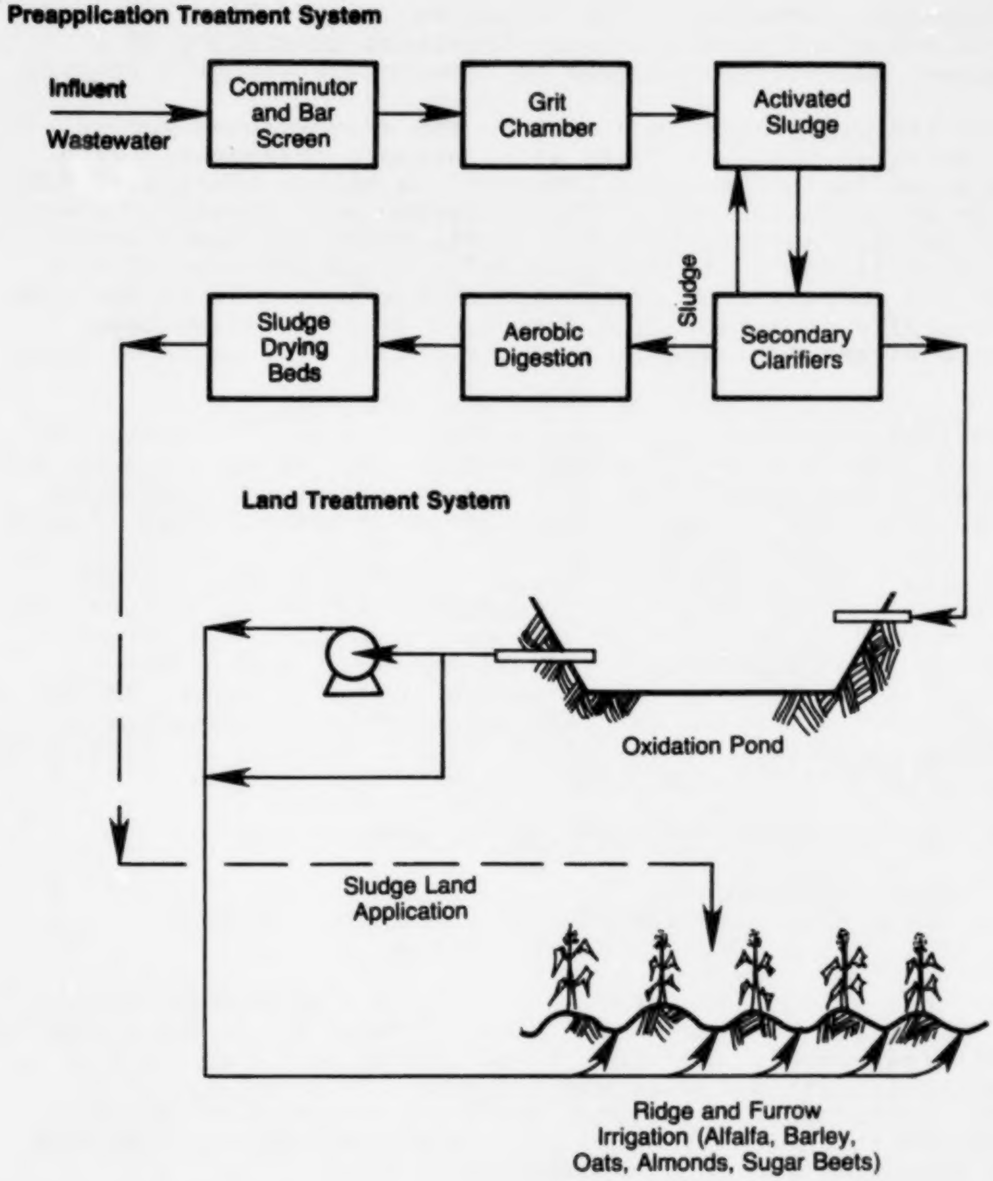

Preapplication Treatment System
Influent
Wastewater
Comminutor and Bar Screen
Grit Chamber
Activated Sludge
Sludge
Secondary Clarifiers
Aerobic Digestion
Sludge Drying Beds
Land Treatment System
Oxidation Pond
Sludge Land Application
Ridge and Furrow Irrigation (Alfalfa, Barley, Oats, Almonds, Sugar Beets)

Figure A-38. Process flow diagram of City of Kerman wastewater treatment plant (# 013), Kerman, California.

PHYSICAL FACILITIES

Wastewater received at the Kerman Wastewater Treatment Plant is first subjected to preliminary treatment consisting of a handcleaned bar screen followed by comminution and grit removal.

Then the wastewater is pumped to the above-ground activated sludge aeration basins. There is no primary treatment. From the aeration basin the mixed liquor flows to two clarifiers followed by an oxidation pond. The oxidation pond covers an area of 0.93 ha (2.3 acres), is 1.5 m (5 ft) deep, and has a total capacity of 11,356 m^3 (3 mil gal) and a detention time of 5.8 days at the current flow rate. All sludge generated at the site is aerobically digested, then dewatered on sand drying beds. The dried digested sludge is land applied on City-owned or other lands.

The land treatment site consists of 87.8 ha (217 acres) of farm land (Figure A-39). Of the 87.8 ha (217 acres), 6.9 ha (17 acres) are owned by the City of Kerman, whereas the remaining land, 80.9 ha (200 acres) is owned by the private farmer (Figure A-39). All irrigation is by a ridge and furrow system utilizing siphon pipes from earthen ditches. Depending on the distance to the field being irrigated, the wastewater either flows from the oxidation pond by gravity or is pumped by a 2.2-kw (3 hp) centrifugal nonclog pump rated at 0.032 m^3/s (500 gpm). The wastewater is distributed to an underground pipe system at the land treatment site. Valve header pipes then distribute the wastewater to earthen ditches from which siphon pipes distribute the wastewater to the ridge and furrow system.

The following crops (including end use) are grown:

1. Cotton for cloth.
2. Sugar beets and almonds for human consumption.
3. Barley and alfalfa for cattle feed.

The soil at the land treatment site is a sand and loam mixture. There are no groundwater monitoring wells in the vicinity of the Kerman plant, and there is no buffer zone between the wastewater-irrigated fields and the other neighboring fields. Typically, stormwater generated runoff from the site is not a problem due to the sandy soil. No attempt is made to keep the public away from the land application site.

The only analytical data available are for the influent to the oxidation ponds. Based on this, and excluding evaporation, the following application rates have been calculated:

Hydraulic	0.89 m/yr 17.0 mm/wk

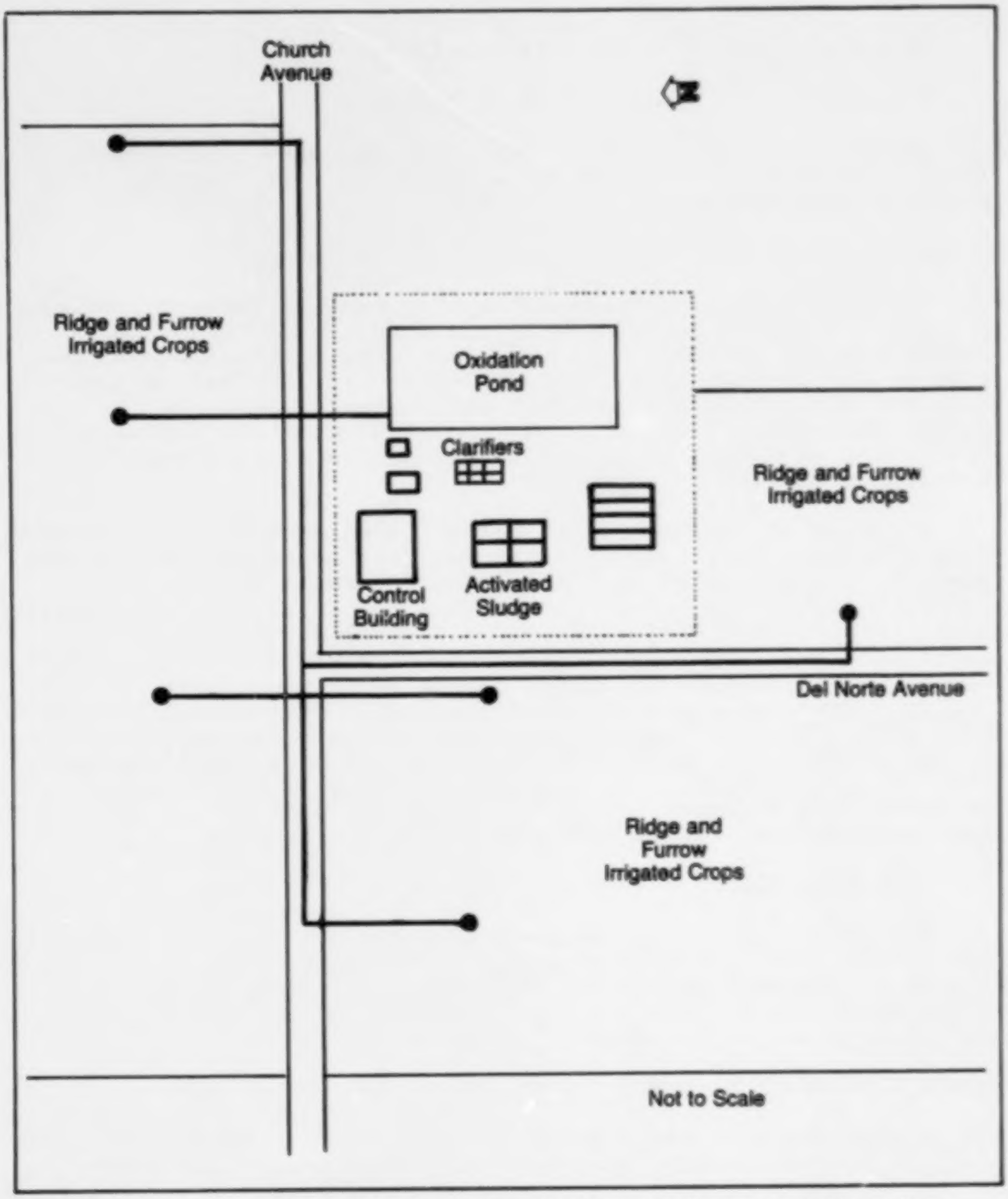

Church Avenue
N
Ridge and Furrow Irrigated Crops
Oxidation Pond
Clarifiers
Ridge and Furrow Irrigated Crops
Control Building
Activated Sludge
Del Norte Avenue
Ridge and Furrow Irrigated Crops
Not to Scale

Figure A-39. Facility layout of City of Kerman wastewater treatment plant (# 013), Kerman, California.

Organic	89 kg BOD_5/ha/yr
Solids	53 kg SS/ha/yr

Based on the operation of the oxidation pond, the organic loading is probably overestimated while the solid loading is probably underestimated.

FACILITY OPERATIONS

The preapplication treatment system is well run and produces a quality effluent containing 10 and 6 mg/L of BOD_5 and suspended solids, respectively. The land treatment system is operated as any farm would be in terms of general irrigation practices, and irrigation is dependent on crop water requirements. During the winter, however, the alfalfa is commonly overwatered to dispose of excess water. Excess water is not typically a problem during the dry summer.

In terms of operation, the farmer takes care of all irrigating, planting, fertilizing, etc., and even operates the effluent pump as required. Contractually, the agreement is that the farmer pays $1,000 per year for the rights to all the wastewater generated. In addition, the farmer pays $1,250 per year for rights to the 6.9 ha (17 acres) of City-owned land. A five-year lease is used with competitive bidding every five years for the rights. There was no mention made of any operational difficulties associated with utilizing the wastewater. In addition, during the growing season the wastewater is often supplemented with irrigation water. In terms of staffing, City of Kerman personnel spend approximately two hours per week on the land treatment system, mainly checking the oxidation pond.

FACILITY MAINTENANCE

The overall plant maintenance appeared good and the plant has an effective preventive maintenance program. There is very little maintenance associated with the land treatment system, aside from the few valves and maintaining the earthen ditches, and there appeared to be no maintenance problems.

OPERATION AND MAINTENANCE COSTS

A total of $104,850 was spent by the City of Kerman for operation and maintenance of the preapplication and land treatment facilities during fiscal year 1978-1979. Of this total, approximately 2 percent, or $2,152, was spent on the land treatment system consisting of $1,060 in personnel expenses, $92 for electricity, and about $1,000 for insurance. The cost for the entire system is offset by the $2,250 received yearly from the farmer for sale of water and rights to the City-owned property.

DESIGN DEFICIENCIES

Two design deficiencies were noted. The first deficiency involves erosion problems around the oxidation pond, as rip-rap was not installed in enough areas to prevent erosion. The second problem is that the effluent pump does not generate sufficient head to deliver water at an acceptable rate to the furthest fields. This causes insufficient water for proper operation of the distant irrigation areas.

CITY OF MANTECA WASTEWATER QUALITY CONTROL FACILITIES (# 014)

MANTECA, CALIFORNIA

SLOW-RATE SYSTEMS

GENERAL

The City of Manteca, California is located in central California in the San Joaquin Valley, approximately 113 km (70 mi) due east of San Francisco (Figure A-40). The Manteca Wastewater Quality Control Facilities and the majority of the land treatment system are owned and operated by the City of Manteca. A private individual farms an additional piece of property. The facility was visited on May 1, 1980.

The climate in the Manteca area is characterized as mild, semiarid. The yearly average temperature is 15.5°C (60.6°F). The yearly average rainfall is 0.30 m (11.87 in), and the yearly annual estimated Class A pan evaporation is 2.03 m (80 in).

Prior to land treatment, wastewater receives preliminary and biological treatment (Figure A-41). Biological treatment consists of an activated sludge system followed by an oxidation pond which also serves as a holding pond. The land treatment portion of the system consists of 69.6 ha (172 acres) of City-owned farmland, and 36.4 ha (90 acres) of privately-owned farmland. It is operated as a slow-rate irrigation system.

The Manteca Wastewater Quality Control Facilities were designed to handle 0.12 m^3/s (2.8 mgd) during the winter months, and 0.14 m^3/s (3.2 mgd) during the summer months. The projected difference in flow is due to a cannery operation. Current flows have been averaging 0.10 m^3/s (2.3 mgd) of which 0.019 m^3/s (0.44 mgd) of industrial flow is received five days per week.

The current preapplication treatment system has been operational for eight years, whereas the land treatment system has been operational for 17 years.

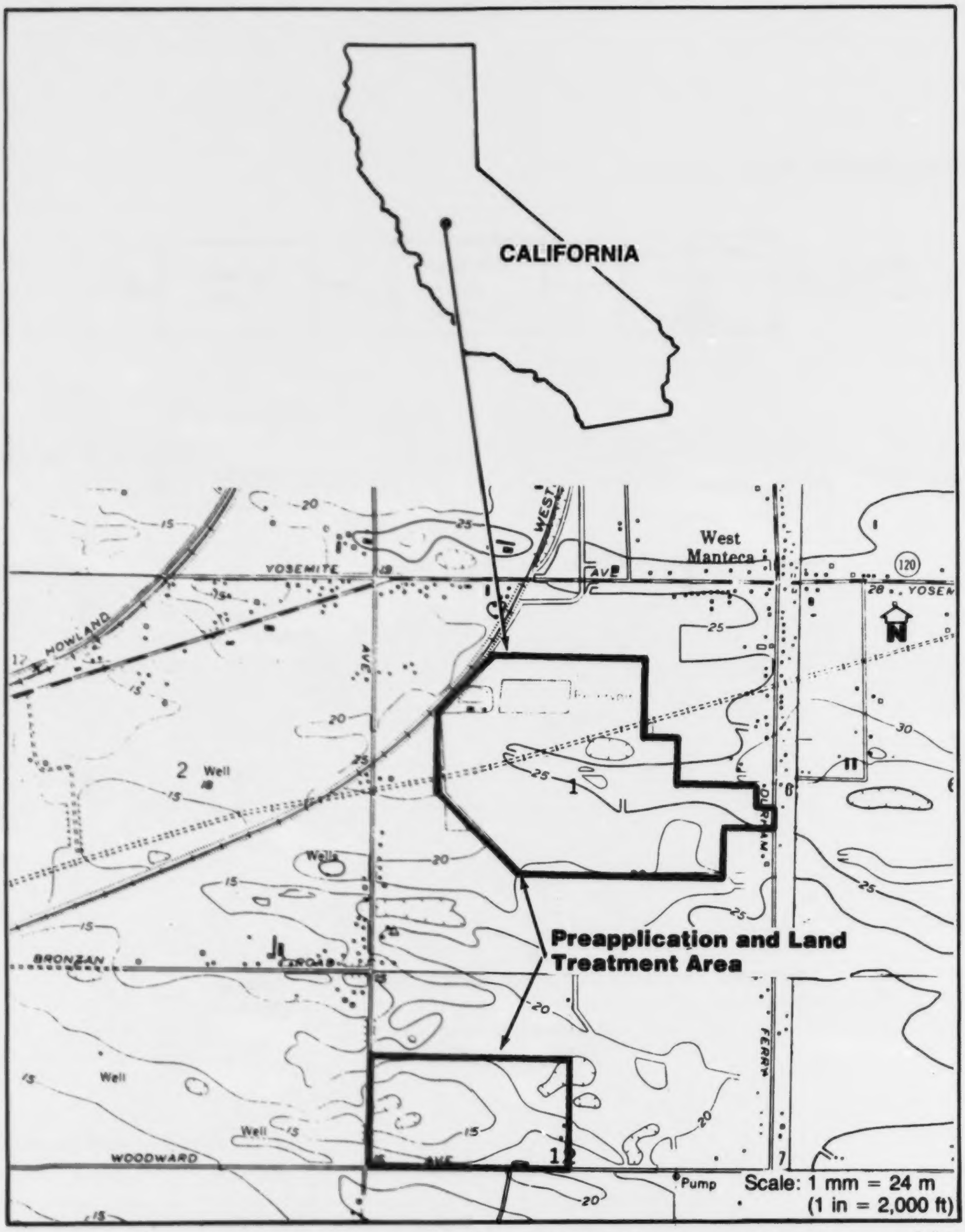

CALIFORNIA
West Manteca
YOSEMITE
AVE
120
HOWLAND
2 Well
Wells
Well
Well
BRONZAN
ROAD
WOODWARD
AVE
Pump
N
Preapplication and Land Treatment Area
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-40. Location map of City of Manteca wastewater quality control facilities (# 014), Manteca, California.

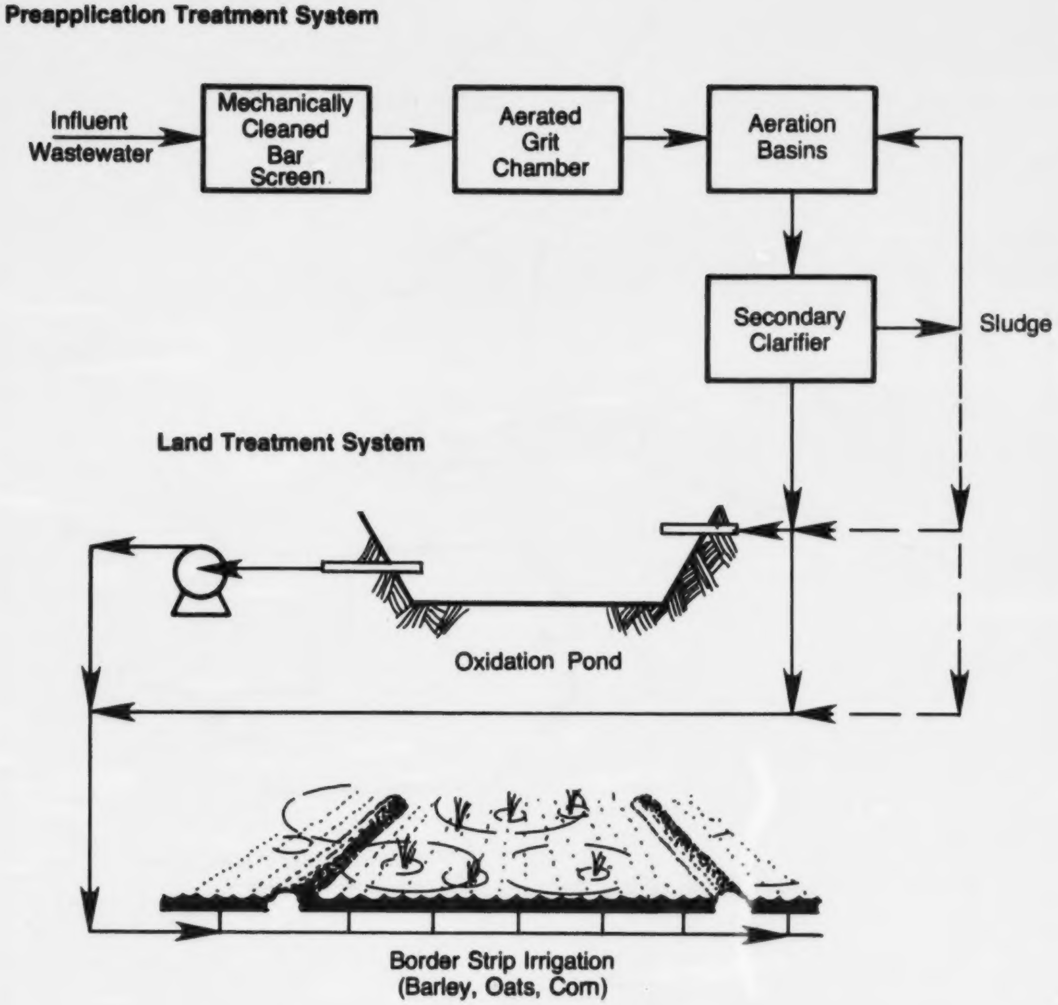

Preapplication Treatment System
Influent Wastewater
Mechanically Cleaned Bar Screen
Aerated Grit Chamber
Aeration Basins
Secondary Clarifier
Sludge
Land Treatment System
Oxidation Pond
Border Strip Irrigation
(Barley, Oats, Corn)

Figure A-41. Process flow diagram of City of Manteca wastewater quality control facilities (# 014), Manteca, California.

The land treatment system is in an area which is predominantly agricultural. There are no plans for changes or modifications at the Manteca Wastewater Quality Control Facilities.

PHYSICAL FACILITIES

All wastewater received at the Manteca Wastewater Quality Control Facilities is first pumped up to a mechanically-cleaned bar screen followed by aerated grit removal. There are no primary treatment facilities at the plant, and the degritted wastewater flows by gravity to an activated sludge unit which is operated in the contact stabilization mode. The mixed liquor then flows to two secondary clarifiers. The clarifiers have no effluent weirs, and wastewater is drawn from the midnatant level utilizing perforated pipe for wastewater collection. The clarified wastewater then flows to an oxidation pond. Approximately seven days of storage is provided in the oxidation pond at the present flow rate. Chlorination is not practiced at the site.

Waste activated sludge from the clarifiers goes either to the oxidation pond, or goes out directly with the clarified effluent to the land treatment system. The oxidation pond covers an area of 3.6 ha (9 acres), is 1.98 m (6.5 ft) deep, and contains a volume of 62,080 m^3 (16.4 mil gal). The land treatment system consists of 69.6 ha (172 acres) of City-owned land, which is leased out, plus an additional 36.4 ha (90 acres) of land that is owned by the farmer who leases the City-owned land (Figure A-42).

According to the contractual arrangement between the leasing farmer and the City of Manteca, a sum of $8,100 is paid for leasing the 76.5 ha (189 acres) of City-owned land for four years. Of this 76.5 ha (189 acres), however, only 69.6 ha (172 acres) is irrigated with wastewater. The farmer is obligated to dispose of all of the wastewater generated by the City of Manteca.

The physical facilities utilized for land treatment of wastewater at Manteca are complicated by a previously-used spray irrigation system that has been replaced by border strip irrigation. Regardless, the flow scheme consists of the following. First, effluent flows either directly to the fields or into the oxidation pond. Once in the oxidation pond the wastewater then flows back by gravity to a wet well and is pumped to a storage tank. From the storage tank all distribution to the fields is by gravity. The pumps used to lift the water from the wet well to the storage tank are two 18.7-kw (25 hp) vertical shaft centrifugal pumps and one 22.4-kw (30 hp) vertical shaft centrifugal pump. The discharge capacity of the pumps is not known.

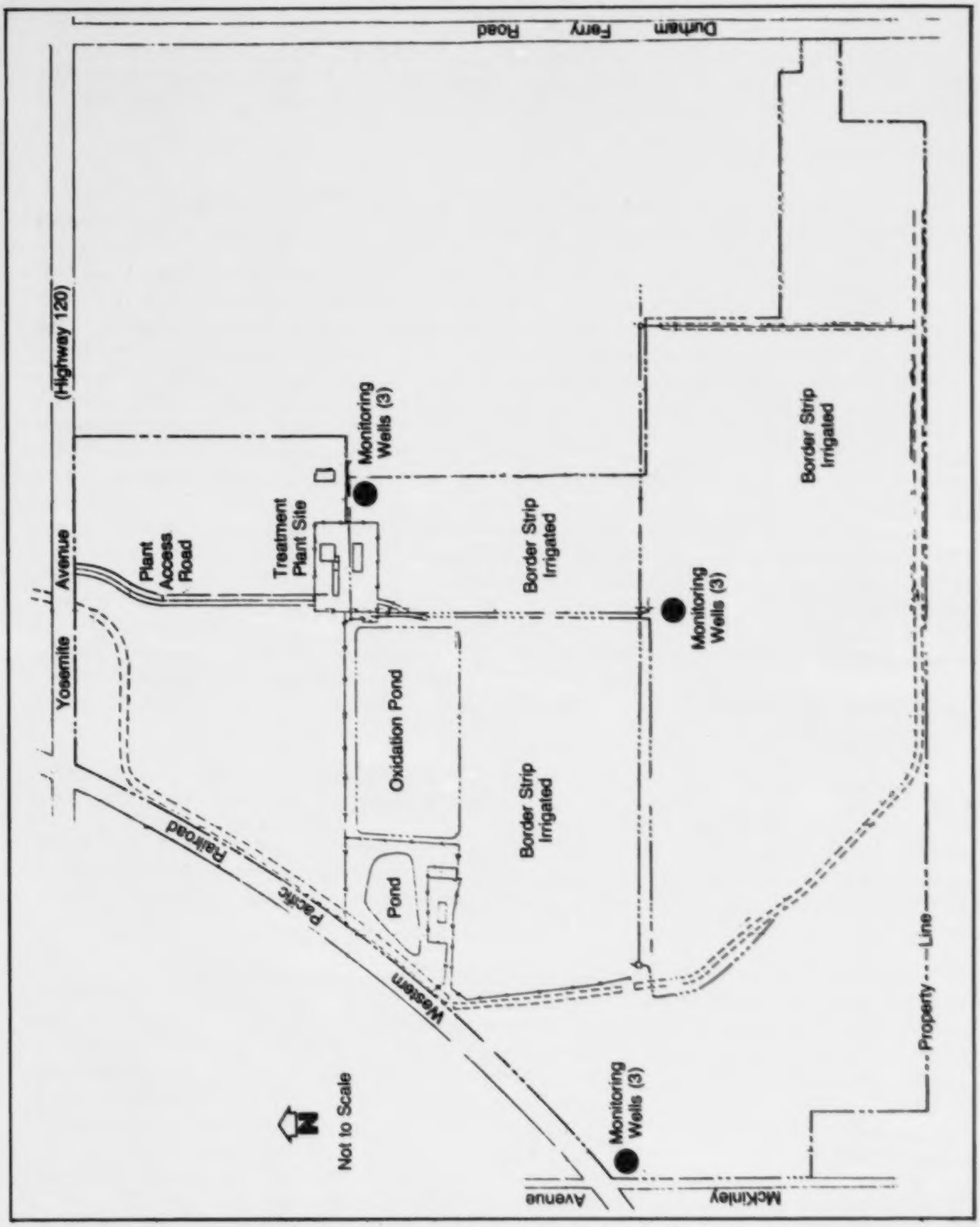

Durham Ferry Road
Yosemite Avenue
(Highway 120)
Plant Access Road
Treatment Plant Site
Monitoring Wells (3)
Border Strip Irrigated
Monitoring Wells (3)
Border Strip Irrigated
Oxidation Pond
Border Strip Irrigated
Pond
Western Pacific Railroad
Monitoring Wells (3)
Property Line
McKinley Avenue
N
Not to Scale

Figure A-42. Facility layout of City of Manteca wastewater quality control facilities (# 014), Manteca, California.

Two additional pumps are also located at the facility. These were used previously for the spray irrigation system, and are currently not being utilized. Wastewater from the storage tank or the treatment plant flows directly by gravity to a distribution box. The distribution box has several electrically-controlled valves whereby the flow to different areas of the site can be controlled from the control room of the treatment plant.

From this distribution box, wastewater flows through underground pipes to the border irrigation fields. Wastewater is diverted into the fields utilizing either diversion chambers with slide gates, or alternatively, individual mechanical gates on each of the border checks. A collection ditch runs along the far end of the border checks to collect any runoff water. This water is diverted to a series of tailwater return pumps which pump the water to a designated field to minimize the potential for mosquitoes and odors. The irrigation system is also connected to the San Joaquin irrigation system, and approximately 5 percent of the total irrigation use consists of fresh water.

The crops grown at the site are fodder crops of barley, oats, and corn. The crops are utilized for dry dairy cows (cows which are not in the milking cycle). The soils at the site consist of sandy loam.

The following application rates have been calculated for the land application site, not including evaporative losses or the effect of the waste sludge that is applied:

Hydraulic	3.0 m/yr 58.4 mm/wk
Organic	1,471 kg BOD_5/ha/yr
Solids	1,382 kg SS/ha/yr
Nutrient	445 kg NH_3-N/ha/yr 16.9 kg NO_3-N/ha/yr

A total of nine groundwater monitoring wells are contained on-site. These wells are located in three groups of three and are at different depths, including 2.4 m (8 ft), 3.7 m (12 ft), and 7.3 m (24 ft).

There is no buffer zone surrounding the irrigation site, and flood irrigation proceeds up to the boundary of the fields. In addition, the area is not fenced, and therefore, there is the possibility for public access. Site runoff is controlled, as tailwaters are returned.

FACILITY OPERATIONS

The preapplication treatment facilities are adequately operated and are producing an intermediate effluent. For the calendar year 1979, effluent quality was as follows:

BOD_5, mg/L	49
Suspended solids, mg/L	45
NH_3, mg/L	18
NO_3, mg/L	2.5
NO_2, mg/L	0.03

The land treatment system as originally designed and constructed in the early 1960's, consisted of a spray irrigation system. This practice was discontinued due to the high cost of labor as two people were required full-time to operate the system. In contrast, the border strip irrigation system requires approximately one-half of a man-day per day. An additional reason is that the spray system was operated at 1,277 kPa (175 psi). This high pressure system utilized the two pumps which are currently not in use and had high operational costs due electrical usage, as well as potentially high maintenance costs.

The current irrigation system is operated 12 months of the year for eight hours per day during the day shift. During this shift wastewater flows directly from the treatment plant to the distribution box. At the distribution box the flow is mixed with wastewater from the oxidation pond by way of the wet well and storage tank. The oxidation pond is filled by gravity flow during the second and third shifts of the day. In addition, waste activated sludge is discharged with the effluent during the eight-hour day shift directly to the field. During the remaining 16 hours, sludge is wasted directly to the oxidation pond. Therefore, some of this sludge is mixed with the effluent water that is pumped to the field during the day shift. In summary, the irrigation proceeds at a rate equivalent to three times the average daily flow rate of the treatment plant for eight hours per day.

Since minimal storage capacity exists, the system is operated daily and utilizes all of the wastewater generated in the previous 24-hour period. During summer operation, each field is typically irrigated at 10-to 14-day intervals, whereas in cooler and wetter weather, each field is irrigated at a three-day interval.

There have been no major operational problems with the border strip irrigation system. The only operational problem has involved squirrels and gophers which have dug holes into the oxidation ponds and caused occasional unplanned releases of wastewater to the fields. In terms of operations, all irrigation of City-owned land is done by City of Manteca personnel, a task which requires approximately four hours per day. The farming operations, however, are conducted by the private farmer. On the separate plot of land owned by the farmer, both irrigation and farming are handled by the farmer.

FACILITY MAINTENANCE

The overall plant maintenance at the Manteca Wastewater Quality Control Facilities is very good, and there is a good preventive maintenance program in force. The simplicity of the land treatment system minimizes the need for much maintenance. All of the equipment associated with the land treatment system is used frequently, is operational, and is therefore adequately maintained. No major maintenance problems were reported for the land treatment system.

OPERATION AND MAINTENANCE COSTS

A total of $331,986 was spent during fiscal year 1979-1980 on preapplication treatment and land application. Of this total, approximately 9 percent, or $28,860, was associated with land treatment expenditures. The major expense was personnel at $15,624. Electricity and utilities were $8,462, and insurance was $4,775.

DESIGN DEFICIENCIES

Due to their location in some of the fields, it was difficult to gain access to various valves and structures. Therefore, attempts should be made to place distribution valves and structures in more easily accessible areas, and have an arrangement which permits easy operator access.

EL DORADO HILLS WASTEWATER TREATMENT PLANT (# 015)

EL DORADO HILLS, CALIFORNIA

SLOW-RATE SYSTEM

GENERAL

El Dorado Hills, California is located in central California approximately 48.3 km (30 mi) west of Sacramento (Figure A-43). The wastewater preapplication treatment facility is owned and operated by the El Dorado Irrigation District in Placerville, California. The land treatment system is operated by a nearby golf course. The facility was visited on May 2, 1980.

El Dorado Hills, California has a seasonal climate with a yearly average temperature of 13.1°C (55.5°F). The yearly average precipitation is 1.01 m (39.79 in). The estimated annual Class A pan evaporation is 1.65 m (65 in).

The El Dorado Hills Wastewater Treatment Plant produces a secondary treated effluent utilizing primary sedimentation, trickling filtration, chlorination, and a final oxidation pond step (Figure A-44). Land application consists of spray irrigation on the nearby El Dorado Hills Golf Club. An additional use of wastewater is spraying logs prior to their use to prevent the logs from discoloring.

The El Dorado Hills Wastewater Treatment Plant is designed to handle 0.033 m^3/s (0.75 mgd) of wastewater. Current flow at the plant has been 0.020 m^3/s (0.45 mgd) of which 100 percent is of domestic origin. The treatment plant has been in operation for approximately 19 years. The spray irrigation at the golf course commenced approximately five years ago during the drought of the mid-1970's.

At the time of the site visit the land treatment system was not in use because it was being upgraded, as was the preapplication treatment facility. Plant upgrading consists of adding grit removal, preaeration, effluent storage, and both low- and high-head effluent pumping. The facility is located in a basically agricultural area.

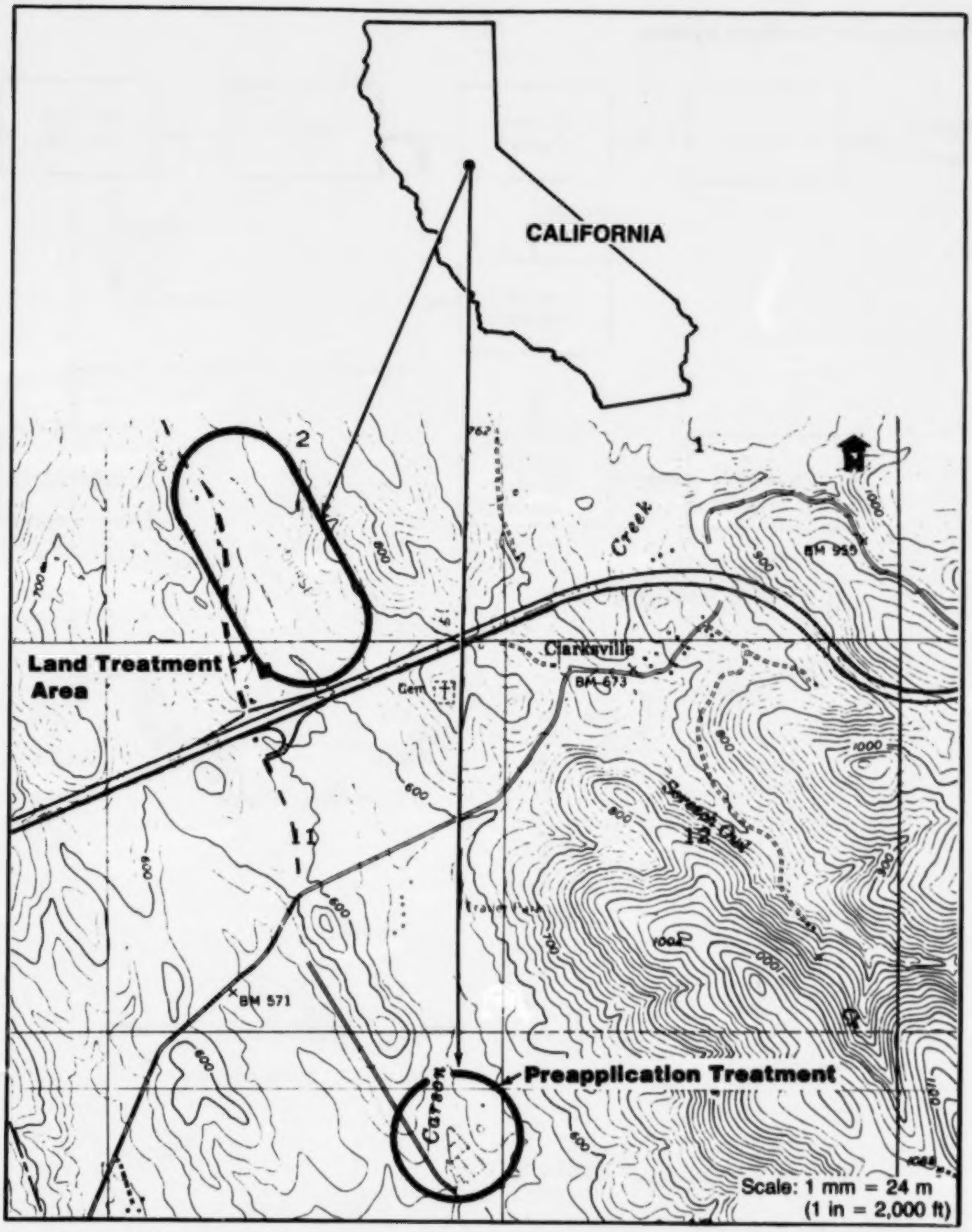

CALIFORNIA
2
1
Creek
BM 955
762
800
700
Clarksville
BM 673
Land Treatment Area
Cem
1000
800
12
11
600
700
BM 571
Preapplication Treatment
Carson
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-43. Location map of El Dorado Hills wastewater treatment plant (# 015), El Dorado Hills, California.

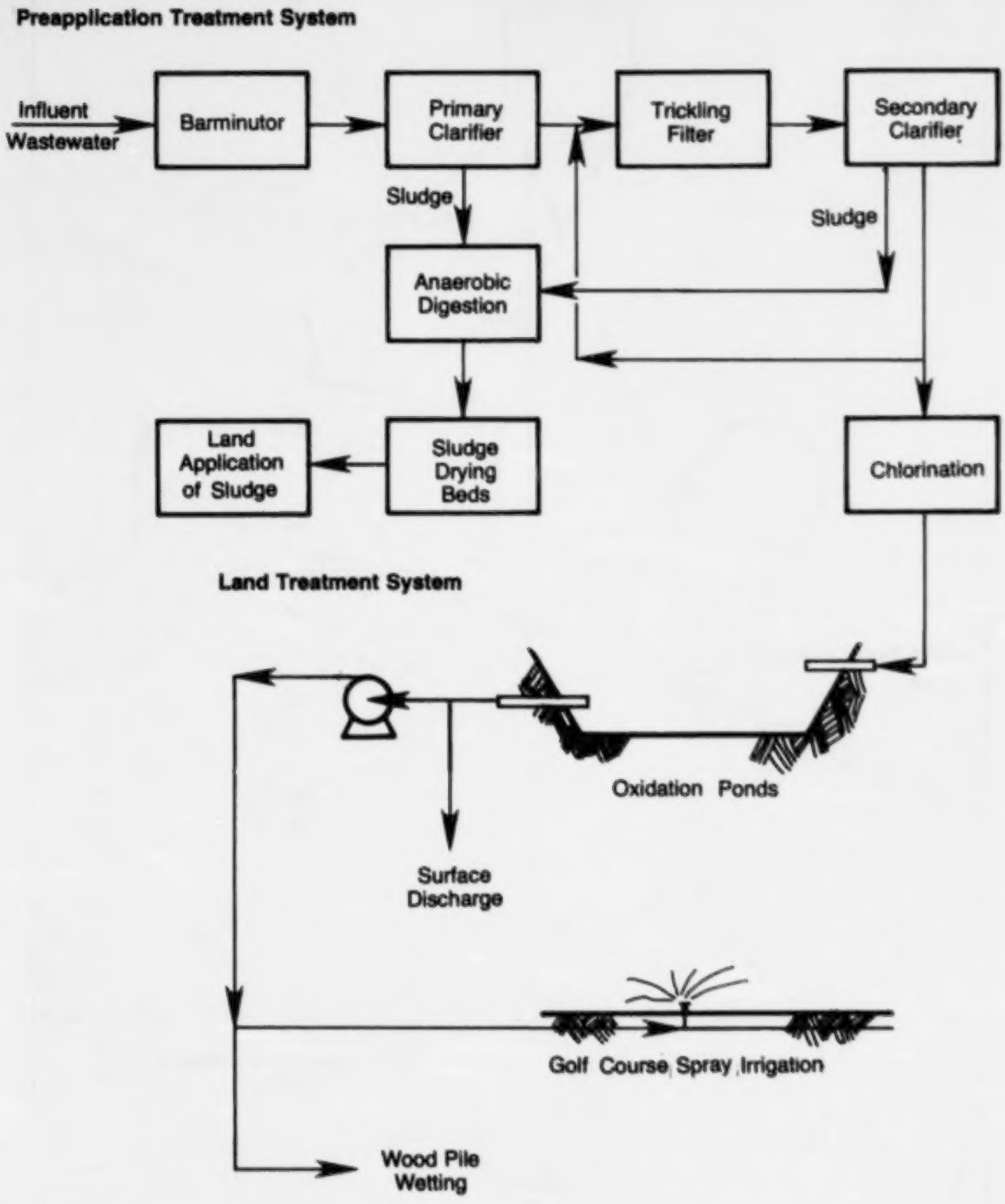

Preapplication Treatment System
Influent Wastewater
Barminutor
Primary Clarifier
Trickling Filter
Secondary Clarifier
Sludge
Sludge
Anaerobic Digestion
Land Application of Sludge
Sludge Drying Beds
Chlorination
Land Treatment System
Oxidation Ponds
Surface Discharge
Golf Course Spray Irrigation
Wood Pile Wetting

Figure A-44. Process flow diagram of El Dorado Hills wastewater treatment plant (# 015), El Dorado Hills, California.

PHYSICAL FACILITIES

Effluent to the El Dorado Hills Wastewater Treatment Plant is first subjected to a barminutor with a by-pass bar screen. Following preliminary treatment, the wastewater flows to one rectangular primary clarifier. From the primary clarifier wastewater flows to a rotary arm high-rate trickling filter followed by one secondary clarifier. Primary and secondary sludge (trickling filter humus) is pumped to one single-stage anaerobic digester, following which the sludge goes to sand drying beds for dewatering, and is eventually land applied. The secondary clarifier effluent is chlorinated and flows to four oxidation ponds in series.

Three of the oxidation ponds cover approximately 0.40 ha (1 acre) each, whereas the fourth pond covers an area of 0.13 ha (0.33 acre). The ponds are 1.5 m (5 ft) deep and contain a total volume of 20,540 m^3 (5.4 mil gal). Approximately 7.2 days of storage is afforded by the oxidation ponds at the design flow rate. In addition, facilities for surface discharge to Carson Creek exist. The land treatment system consists of spray irrigation at the El Dorado Hills Country Club which is an approximately 9.1-ha (20 acre) golf course. It is located approximately 1.6 km (1 mi) northeast of the treatment plant (Figure A-45). The soils in the vicinity of the golf course are a mixture of loam and silt. There are no groundwater monitoring wells in or around the golf course, and obviously there is no buffer zone nor is site access controlled. Under typical operations no site runoff would be generated.

Approximately 50 percent of the wastewater treated at the El Dorado Hills Wastewater Treatment Plant is utilized by the Golden State Building Products Wood Veneer Plant where the wastewater is sprayed on wood logs. By keeping the logs wet, the wood does not blue (discolor) and therefore retains a higher economic value. The wastewater at this site is sprayed on the logs, and a certain amount percolates into the groundwater although runoff is collected and reapplied.

Presently, the only storage is that afforded by the oxidation ponds. However, the addition of a 60,566 m^3 (16 mil gal) holding tank will provide a detention time of 21.3 days at the design flow.

FACILITY OPERATIONS

During the site visit the facility operations were altered from normal conditions due to the construction and upgrading at

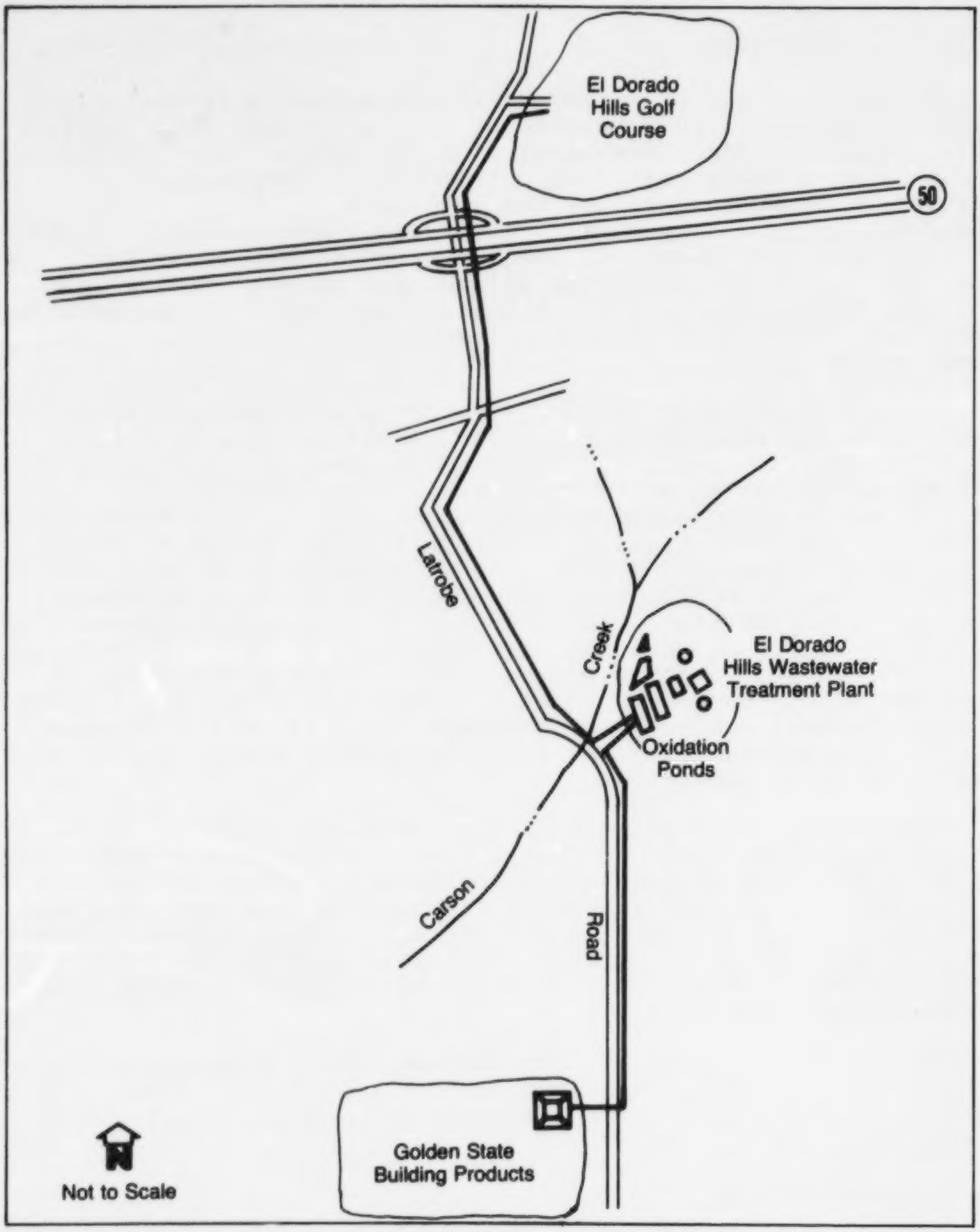

El Dorado Hills Golf Course
50
Latrobe
Road
Creek
Carson
El Dorado Hills Wastewater Treatment Plant
Oxidation Ponds
Golden State Building Products
N
Not to Scale

Figure A-45. Facility layout of El Dorado Hills wastewater treatment plant (# 015), El Dorado Hills, California.

the facility. Based on analytical data from calendar year 1979, the plant meets secondary treatment requirements by producing an effluent with average BOD_5 and suspended solids of 7.8 and 12.5 mg/L, respectively. The geometric mean of the total coliforms is less than 3.4 counts per 100 ml.

The land treatment portion of the system was not operational during our visit due to the upgrading activities. The system was initiated in 1975 at the height of the drought, and was designed and constructed in a hurry. Various operational problems were subsequently encountered by operating personnel at the golf course. One problem was that their sprinklers were getting clogged with small minnows (small fish put in the lagoons to control mosquitos). A second minor problem involved the slight odors that were occasionally present. To alleviate problems with the fish, screening provisions have been made in the new pump station to minimize the problem of sprinkler head clogging.

In terms of contractual agreement, the El Dorado Hills Country Club currently pays $100 per month, plus $0.03 per m^3 ($0.87 per 100 ft^3). The Golden State Building Products Company pays $100 per month, plus $0.018 per m^3 ($0.50 per 1,000 ft^3). Although the golf course is currently not purchasing any water, plans call for all wastewater to be reclaimed starting in 1981 after completion of the upgrading at the El Dorado Hills Wastewater Treatment Plant.

FACILITY MAINTENANCE

At the time of the site visit the treatment plant was undergoing major construction, therefore it would be hard to assess the maintenance practices at the facility. In addition, equipment at the golf course was also not inspected as it was currently nonoperational. In terms of maintenance, the problem of sprinkler clogging due to fish and other debris has already been discussed.

OPERATION AND MAINTENANCE COSTS

The costs of the El Dorado Hills Wastewater Treatment Plant operation and maintenance were not available from the El Dorado Irrigation District as the budgets for the various treatment plants are lumped together. Regardless, the land application system was not operational, and therefore, no costs would have been available.

DESIGN DEFICIENCIES

The following design deficiencies were noted during the plant visit. The first one is the problem of minnows and algae which caused sprinkler clogging and should have been taken care of with some sort of prescreening. The second design deficiency was that the original pump did not have sufficient capacity to meet the required peak loads of the golf course. These peak loads were both hourly and seasonal.

All of these design deficiencies have been adequately addressed in the design of the new treatment facility pumping station. Hopefully, enough was learned by the previous errors to minimize future problems.

U.S. ARMY CORPS OF ENGINEERS WATERWAYS EXPERIMENTAL STATION OVERLAND FLOW SITE (# 016)

UTICA, MISSISSIPPI

OVERLAND FLOW SYSTEM

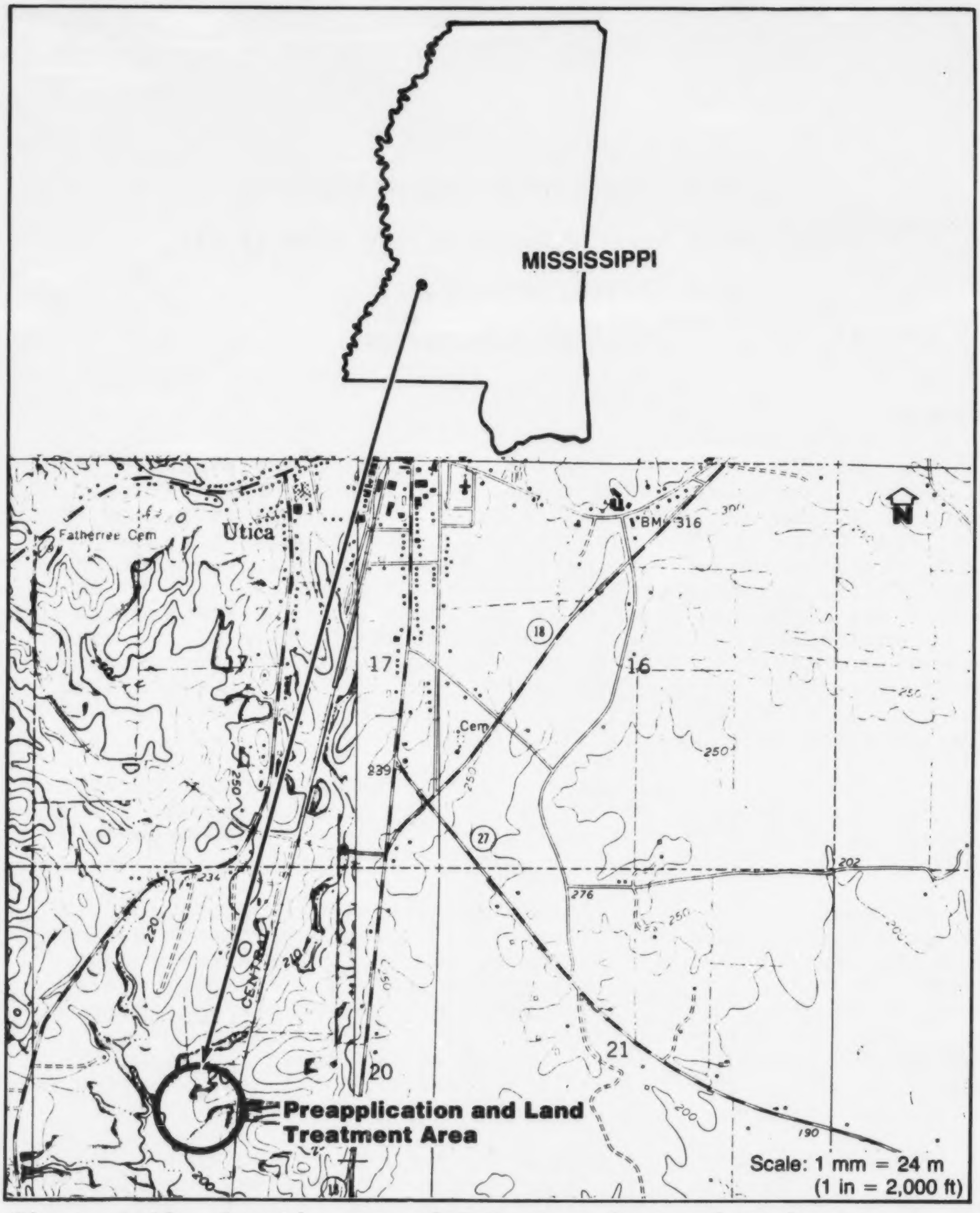
GENERAL

The Town of Utica, Mississippi is located approximately 39 km (24 mi) southeast of Vicksburg, Mississippi (Figure A-46). Utica is a town of approximately 1,000 people. In 1975, the U.S. Army Corps of Engineers Waterways Experimental Station (WES) established an overland flow field installation at Utica. The facility was established for research purposes, and the research was supported jointly by the Corps of Engineers and the U. S. Environmental Protection Agency. At the time of the visit on May 12, 1980 the facility had been shut down for approximately three months as the research had concluded. As there are so few overland flow sites in the United States, the facility was visited although it was not operational.

The climate of Utica, Mississippi is mild, with yearly average temperatures of 18.8°C (65.8°F). The average annual precipitation for the area is 1.31 m (51.47 in). The mean annual Class A pan evaporation is estimated to be 1.52 m (60 in).

Wastewater at the Utica overland flow site is pretreated in two oxidation ponds. Approximately 33 percent of the oxidation pond effluent is then pumped to the overland flow site (Figure A-47). The overland flow site consists of 24 individual fields constructed on slopes of 2, 4, and 8 percent with eight plots on each slope. Influent to the oxidation ponds averages 254 m^3/day (67,000 gpd). Of this total, it is estimated that approximately 76 m^3/day (20,000 gpd) was treated at the overland flow site. The wastewater was 100 percent domestically generated.

The preapplication treatment has been in operation for approximately 15 years. The land treatment system had been in operation for four years when it was shut down in early 1980. The facility is located in a basically agricultural area. There are no future plans for this facility, and the land, which was



MISSISSIPPI
Utica
Fatherree Cem
BM 316
Cem
17
16
20
21
18
27
202
276
250
Preapplication and Land Treatment Area
Scale: 1 mm = 24 m
(1 in = 2,000 ft)
N

Figure A-46. Location map of U.S. Army Corps of Engineers Waterways Experimental Station overland flow field installation (# 016), Utica, Mississippi.

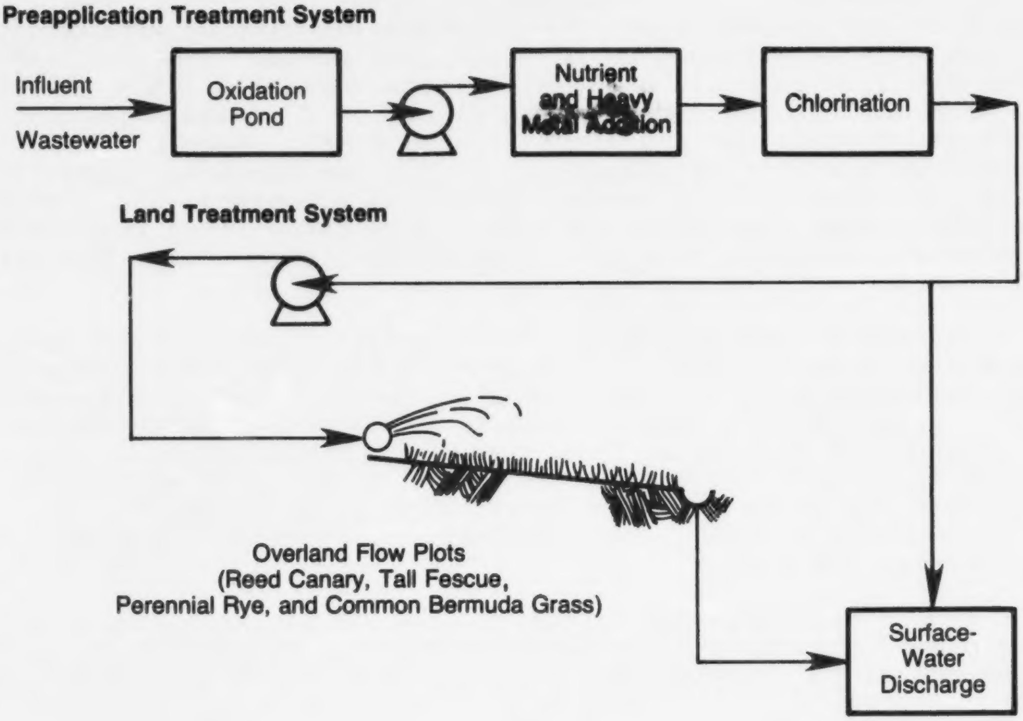

Preapplication Treatment System
Influent
Wastewater
Oxidation Pond
Nutrient and Heavy Metal Addition
Chlorination
Land Treatment System
Overland Flow Plots
(Reed Canary, Tall Fescue,
Perennial Rye, and Common Bermuda Grass)
Surface-Water Discharge

Figure A-47. Process flow diagram of U.S. Army Corps of Engineers Waterways Experimental Station overland flow field installation (# 016), Utica, Mississippi.

leased from a local farmer, is going to be regraded and returned to its natural slope, with all of the equipment removed.

PHYSICAL FACILITIES

The preapplication treatment oxidation ponds cover a total area of 2.4 ha (6 acres) and are approximately 1.5 m (5 ft) deep. There is a total capacity of 37,000 m^3 (9.8 mil gal). Based on the current flow rate, a detention time of approximately 146 days is afforded by the oxidation ponds. The overland flow facility consists of 24 plots each measuring 4.6 m (15 ft) by 46 m (150 ft), constructed on slopes of 2, 4 and 8 percent with eight plots on each slope (Figure A-48). Each plot was seeded with a 5:2:2:1 mixture of four grass species: reed canary, Kentucky 31 tall fescue, perennial rye grass, and common Bermuda grass. The plots were seeded at three times the recommended agricultural rate to insure dense grass cover. The soil beneath the site is a silty clay loam.

Wastewater was pumped from the oxidation ponds to the overland flow site utilizing one 3.7-kw (5 hp) pump. The wastewater was delivered to a wet well, from which point individual plots were irrigated utilizing 0.75-kw (1 hp) pumps. Wastewater application was controlled by a time clock connected to a solenoid valve in series with a flow regulator device. The wastewater was then pumped to a trough constructed of rain gutter. Holes in the bottom of the trough were used to distribute the wastewater across the plot.

Runoff was collected at the far end of the plot in a sump, and pumped through a water meter to measure the volume of runoff from the plot. Samples were taken periodically to determine water quality.

No groundwater monitoring wells were installed in conjunction with the facility. In terms of a buffer zone, the nearest house was approximately 0.4 km (0.25 mi). Off-site stormwater runoff could not flow onto the site due to the slope of the land. Stormwater generated inside the overland flow plots would be discharged with the process water. Public access is permitted to the land application site, but is controlled by a sign.

Pond effluent was lower in nitrogen, phosphorus, and heavy metals than typical wastewater across the country. Therefore, nutrient addition as ammonium chloride, and di-ammonium phosphate and heavy metals as chlorides were injected into the oxidation pond effluent prior to irrigation. In this way, the total nitrogen was increased to 20 mg/L, total phosphorus to 10 mg/L, and various metals were also elevated.

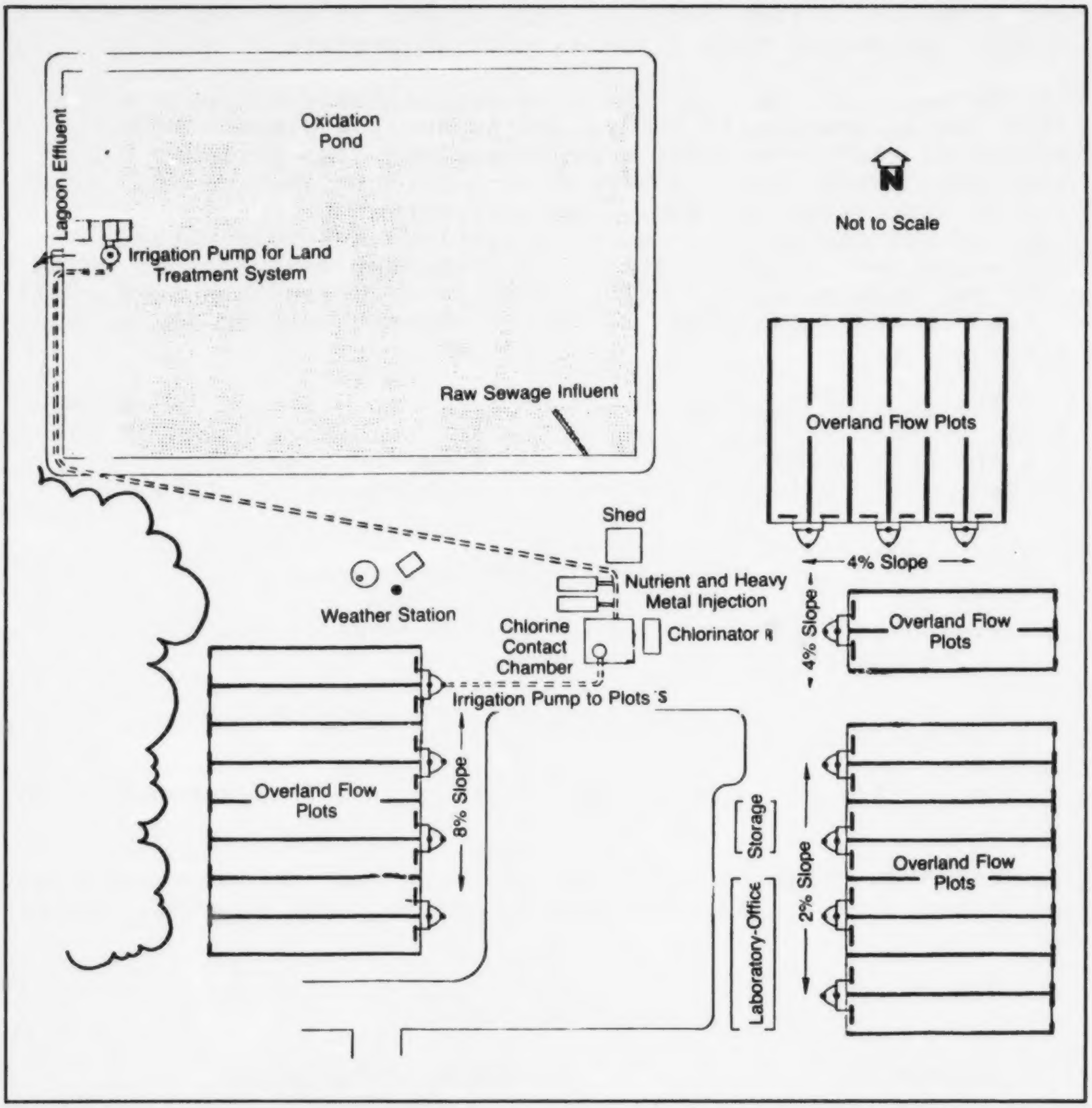

Oxidation Pond
Lagoon Effluent
Irrigation Pump for Land Treatment System
Raw Sewage Influent
N
Not to Scale
Overland Flow Plots
4% Slope
Shed
Nutrient and Heavy Metal Injection
Weather Station
Chlorine Contact Chamber
Chlorinator
Overland Flow Plots
4% Slope
Irrigation Pump to Plots
Overland Flow Plots
8% Slope
Storage
Laboratory-Office
2% Slope
Overland Flow Plots

Figure A-48. Facility layout of U.S. Army Corps of Engineers Waterways Experimental Station overland flow field installation (# 016), Utica, Mississippi.

FACILITY OPERATIONS

The preapplication treatment was effective in substantially reducing the loading on the overland flow facility. The BOD_5 and suspended solids averaged only 22 and 35 mg/L during the study. pH varied from 7 to 11, with an average pH of 9.

In terms of the overland flow application, effluent to each plot was automatically controlled to apply a predetermined amount of wastewater over a predetermined time period. A flow regulator was adjusted to apply from 12.7 to 50.8 mm (0.5 to 2 in) of wastewater per day. The application period was set by opening and closing an electrically-timed solenoid valve. Application periods of 6, 18, or 24 hours per day, five or seven days per week were evaluated. Therefore, all of the land application was on a schedule due to the research nature of the project.

The grasses were harvested three times per year in spring, early summer, and early fall. Various parameters such as nutrient and metals levels were tested, then the grasses were discarded. The following operational problems were noted:

1. Orifices of the solenoid valves were only 19 mm (0.75 in), and were subject to plugging.
2. Water meters which were used to measure plot effluent typically plugged.
3. The gutter distribution system plugged at the outlets.

One full-time operator was involved with facility operation and maintenance.

Based on the preapplication effluent quality (after nutrient addition), the following range of loading rates have been calculated:

Hydraulic	3.3 to 13.2 m/yr 63.5 to 254 mm/yr
Organic	87.6 to 349 kg BOD_5/ha/yr
Solids	139 to 555 kg SS/ha/yr
Nutrient	55 to 222 kg NH_3-N/ha/yr 39.3 to 158 kg T-P/ha/yr

FACILITY MAINTENANCE

At the time of the visit, the facility was not operational; therefore, it would be hard to assess maintenance practices. However, the problems with the solenoid valves, and water meter and gutter distribution plugging were the kinds of maintenance problems with which the facility had to contend.

OPERATION AND MAINTENANCE COSTS

Due to the research nature of the project, it was deemed inappropriate to collect operation and maintenance costs as they would reflect the research nature of the project.

DESIGN DEFICIENCIES

Three design deficiencies were previously noted: plugging of solenoids, distribution piping, and water meters.

FALKNER WASTEWATER TREATMENT FACILITY (# 017)

FALKNER, MISSISSIPPI

OVERLAND FLOW SYSTEM

GENERAL

The City of Falkner, Mississippi is located in the north-central portion of Mississippi, approximately 121 km (75 mi) southeast of Memphis, Tennessee (Figure A-49). The Falkner wastewater treatment and land treatment facilities are owned and operated by the City of Falkner. The facility was visited on May 13, 1980.

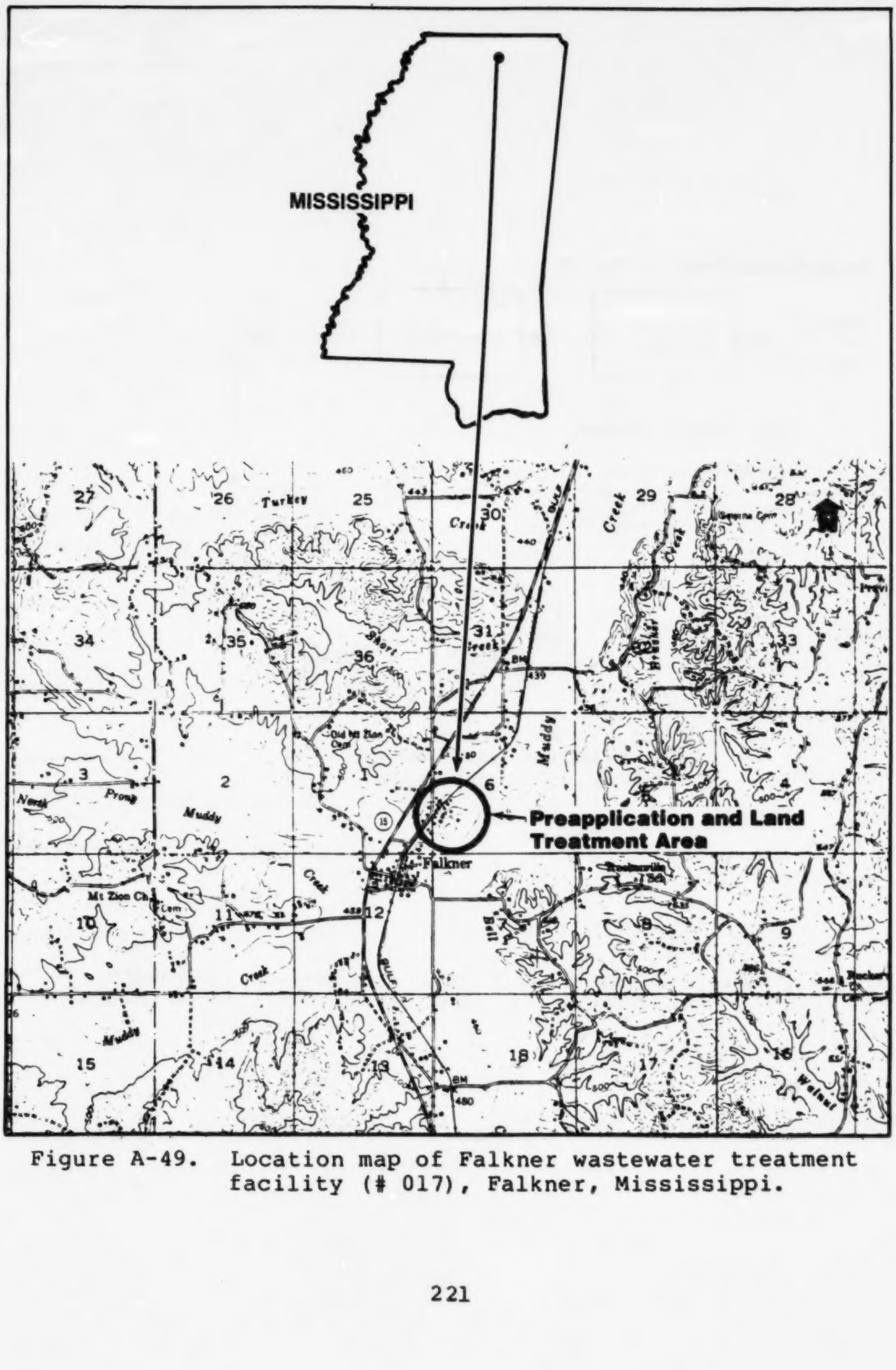
The climate in the Falkner area is characterized by relatively mild winters and hot, humid summers. The yearly average temperature in the area is 15.9°C (60.7°F). The yearly average precipitation is 1.38 m (54.31 in), and the mean annual Class A pan evaporation is 1.40 m (55 in).

The preapplication treatment at the Falkner Wastewater Treatment Facility consists of an oxidation pond. Wastewater from the oxidation pond is then chlorinated and sprayed on one of three overland flow fields (Figure A-50). The effluent from the fields then flows to Muddy Creek. The Falkner Wastewater Treatment Facility was designed to handle 132 m^3/day (35,000 gpd). There is no influent flow meter at the facility, however, current flows are estimated to be 106 m^3/day (28,000 gpd). The Falkner treatment facility receives no industrial flow; all flow is either domestic or commercially generated. The preapplication treatment and land application system have been operational for three years.

The entire treatment facility is located in an agricultural area with some residences in the area. There are no future plans for changes or modifications to the facility.

PHYSICAL FACILITIES

Wastewater from the City of Falkner flows from a sanitary sewer collection system into a lift station, and is pumped directly to the oxidation pond. The pond influent enters


MISSISSIPPI
Preapplication and Land Treatment Area
Falkner
Turkey
Creek
Short Creek
Muddy
North Prong
Muddy
Creek
Mt Zion Ch
Old Mt Zion Cem
Bill
Walnut
27
26
25
30
29
28
34
35
36
31
33
3
2
6
4
10
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16

Figure A-49. Location map of Falkner wastewater treatment facility (# 017), Falkner, Mississippi.

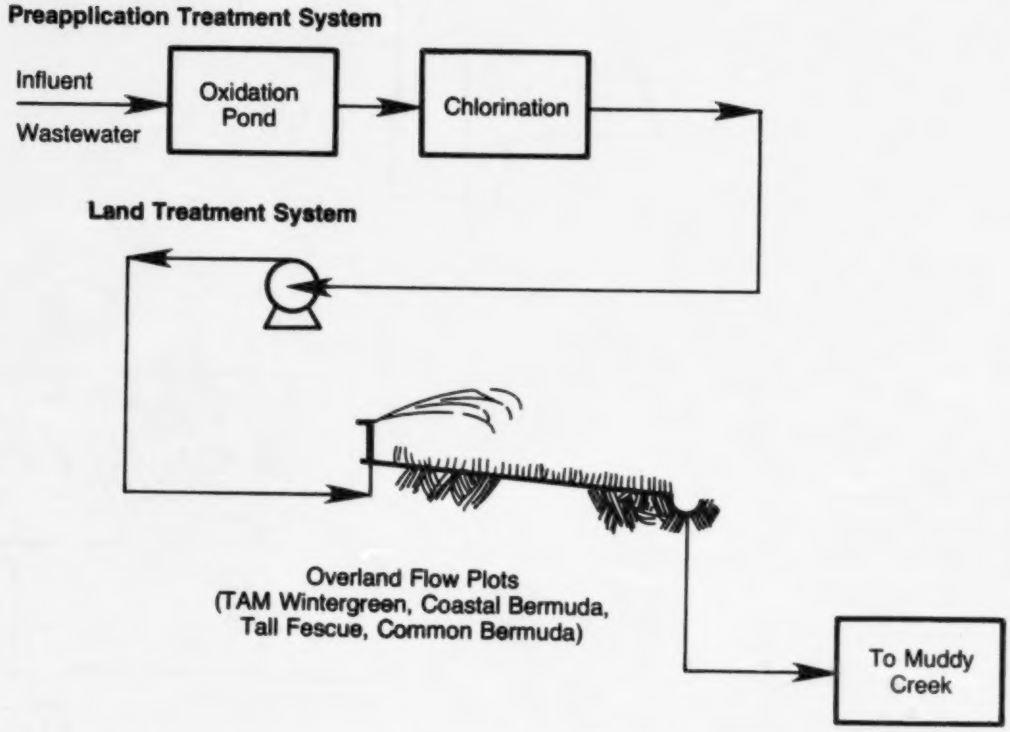
Preapplication Treatment System
Influent
Wastewater
Oxidation Pond
Chlorination
Land Treatment System
Overland Flow Plots (TAM Wintergreen, Coastal Bermuda, Tall Fescue, Common Bermuda)
To Muddy Creek

Figure A-50. Process flow diagram of Falkner wastewater treatment facility (# 017), Falkner, Mississippi.

through a standpipe. The pond covers an area of 0.82 ha (2.03 acres), and the maximum operating depth is 2.1 m (7 ft). At this depth the pond will hold 17,390 m^3 (4.6 mil gal). The pond is unlined and has a design detention time of 131 days.

The wastewater overflows a variable level weir in the oxidation pond and enters the chlorine contact tank. The contact tank is excavated out of the existing soil and utilizes bulkheads made of creosote-soaked wood as baffles. A gaseous chlorine eductor system is utilized to supply chlorine from two 68.2-kg (150 lb) cylinders.

Following chlorination the wastewater is pumped to the overland flow fields by two vertical shaft centrifugal nonclog pumps, 3.73-kw (5 hp), rated at 589 m^3/day (108 gpm). The pumps are mounted on a platform at the end of the chlorine contact tank and are level controlled.

All of the preapplication treatment effluent is applied to the overland flow fields. The fields consist of a 1.06-ha (2.62 acres) area separated between sections by earthen berms (Figure A-51). Two of the three fields have six sprinklers, whereas the third field has five. The 17 sprinklers are Rainbird Model 31 Rotary pop-up sprinklers with adjustable nozzles. The sprinklers are actuated whenever the system is pressurized. The fields themselves are approximately 104 m (340 ft) long by 33.5 m (110 ft) wide. The plots are valved so that one field can be sprayed at a time, if desired. The system is designed to spray 17.8 mm (0.7 in) of wastewater per day at the design flow.

The fields have a slope of 2 to 5 percent toward the tailwater collection ditch. The tailwater that is collected then flows by gravity through a weir and out to Muddy Creek. Three different vegetative combinations are used on each of the spray fields. The first field has a mixture of TAM Wintergreen Harding grass and coastal Bermuda grass. The second plot has reed canary grass mixed with common Bermuda, and the third plot has Kentucky 31 tall fescue and coastal Bermuda grass. The soil at the site is a silty clay loam.

Although there are no storage ponds at the facility, the variable depth allowed by the oxidation ponds affords considerable storage volume. Assuming a minimum depth of 2 feet of water in the pond, the maximum storage possible is 12,520 m^3 (3.31 mil gal), or 91 days at design flow. There are no groundwater monitoring wells on-site. There is no buffer zone on one side of the spray fields as the wastewater is applied almost to the boundary line of the facility.

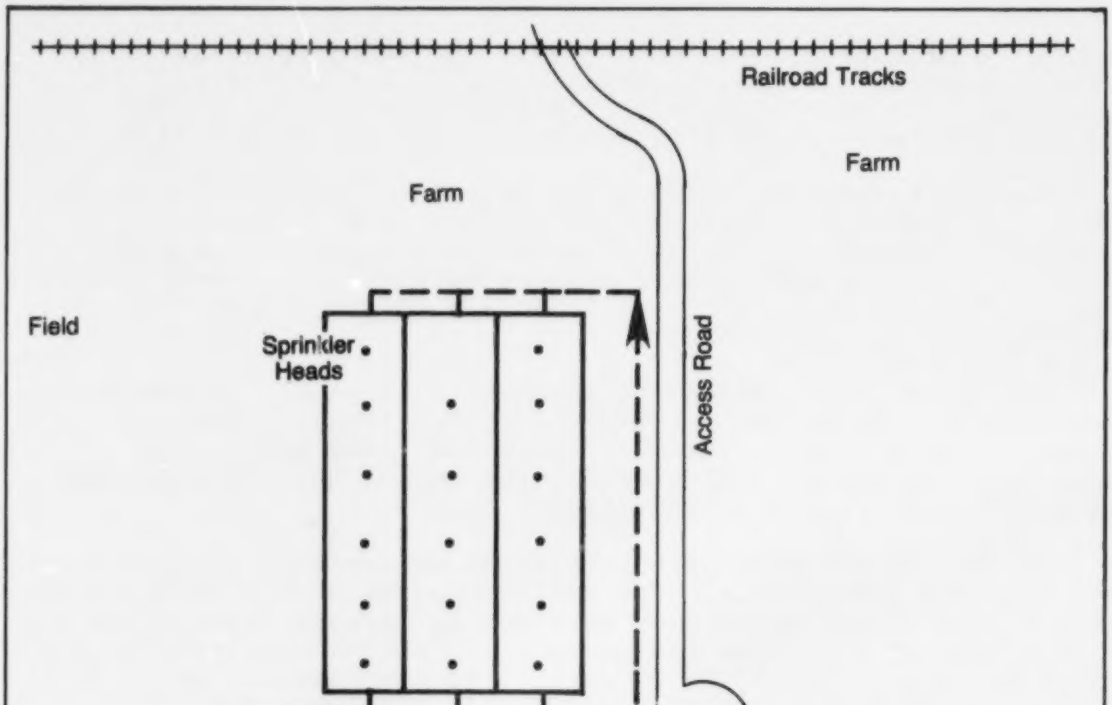
Railroad Tracks
Farm
Farm
Field
Sprinkler Heads
Access Road
Weir
Cl₂ Room
Control Building
Influent Standpipe
Oxidation Pond
Pumps
Muddy Creek
N
Not to Scale

Figure A-51. Facility layout of Falkner wastewater treatment facility (# 017), Falkner, Mississippi.

FACILITY OPERATIONS

Due to the simplicity of the oxidation pond, its operation has little impact on the operation of the overland flow system. There are no analytical data available on the effluent quality from the oxidation ponds.

The overland flow system is operated year-round although measurable runoff generally occurs only from January through April. The typical operating sequence during the winter months is to spray for one day and to wait five days before spraying the particular field again. In the summer, due to evaporation and percolation from the oxidation pond, it may not be necessary to operate the spray fields for several days at a time. Therefore, during the summer months the operational system more closely resembles a slow-rate system than a overland flow system. The superintendent usually works the spray system in a manual mode, and therefore overrides the level controller.

All of the operational work at the facility is performed by the superintendent. This includes cutting the grass and maintaining the facility. Less than 50 percent of his time is spent at the wastewater treatment facility. Based on the results of the four samples taken between January and April 1980 the following overland flow effluent characteristics were obtained:

BOD_5, mg/L	12
Suspended solids, mg/L	20
TKN, mg/L	2.9
Dissolved oxygen, mg/L	8.7
Fecal coliforms, no/100 ml	1,750

The operator reported minimal operating headaches and only occasional sprinkler clogging. The operator did say, however, that he thought the system should be designed so that there would not be any runoff during any part of the year, showing his misunderstanding of the overland flow system.

FACILITY MAINTENANCE

The facility maintenance at the treatment plant appeared good; all maintenance is performed by the superintendent. Maintenance includes mowing the grass both in the spray fields and around the oxidation pond. Grass collected from the spray fields is used in erosion control projects.

Two maintenance problems were reported. First, the tailwater collection ditch, which is located at the base of the oxidation pond and is usually wet, is a tough area to mow. Second, settlement of the spray fields has caused ponding areas.

OPERATION AND MAINTENANCE COSTS

For calendar year 1979, a total of $4,331 was spent on operation and maintenance of the facility. Of this total, approximately 51 percent was spend on the land application system. The breakdown for the funds expended for land application are as follows:

Personnel	$1,665
Materials and supplies	72
Fuels and electricity	100
Maintenance and repairs	378
Total	$2,215

DESIGN DEFICIENCIES

The first design deficiency noted was that the slopes around the oxidation pond were too steep to allow mowing and easy access. The second deficiency was that off-site runoff from an adjacent farmer's field enters the treatment plant site and runs off with the overland flow effluent, and is a potential source of the excessive coliforms in the wastewater.

An additional design deficiency involves the placement of the tailwater collection and disposal channels which are run beside the oxidation pond berm. Also, the weir section of the collection system is not large enough, and the soil has eroded around the concrete. During storm events the weir is not large enough to measure the total flow.

Another problem is that the earth grading and compaction at the time of construction was not sufficient to stop future settlement. This settling has caused ponding problems in the spray fields.

The final design deficiency involves the need for two effluent spray pumps. Due to the inherent stability of the oxidation pond and the storage in the pond itself, there appears to be a need for only one effluent spray pump.

The need for any effluent pumping can be questioned due to the relative hydraulics of the plant, and the fact that all wastewater is pumped to the oxidation pond. It would appear that a gravity distribution system could be utilized in the field, utilizing gated pipes or the like. This would substantially reduce the operating expense and the maintenance headaches associated with level-controlled pumps.

EASLEY COMBINED UTILITIES SYSTEM

OVERLAND FLOW PROJECT (# 018)

EASLEY, SOUTH CAROLINA

OVERLAND FLOW SYSTEM

GENERAL

Easley, South Carolina is located in the northwest portion of South Carolina, approximately 16 km (10 mi) west of Greenville, South Carolina (Figure A-52). The City of Easley is served by several wastewater treatment facilities, which are owned and operated by the Easley Combined Utilities System, among them the Golden Creek lagoon system. Several years back, as part of a cooperative study with Clemson University, the South Carolina Department of Health and Environmental Control, and the U.S. Environmental Protection Agency, a project was begun at the Golden Creek site to study the treatment of both raw and oxidation pond-treated wastewater. The overland flow site was visited on May 15, 1980.

Easley, South Carolina has a temperate climate. The average yearly temperature is 15.4°C (59.8°F), and the average yearly precipitation is 1.32 m (51.9 in). The mean annual Class A pan evaporation is 1.30 m (51 in).

Although there is no flow-measuring device at the Golden Creek oxidation pond, the average daily flow is estimated to be 0.0044 m^3/s (0.1 mgd). The majority of the flow is domestic; however, one cotton mill is served by the system. The oxidation pond has been in operation for 15 to 20 years, but the overland flow project has only been in operation for two years. Prior to the addition of the overland flow facility, there was a surface discharge to Golden Creek. The overland flow system was designed to handle 284 m^3/day (75,000) gpd of oxidation pond effluent, and 95 m^3/day (25,000 gpd) of raw comminuted sewage based on seven-day per week operation.

Future plans for the facility are uncertain due to the research nature of the project, and since the state may require nutrient removal prior to discharge into Golden Creek. The land use adjacent to the overland flow site consists of both agricultural and rural residential areas.

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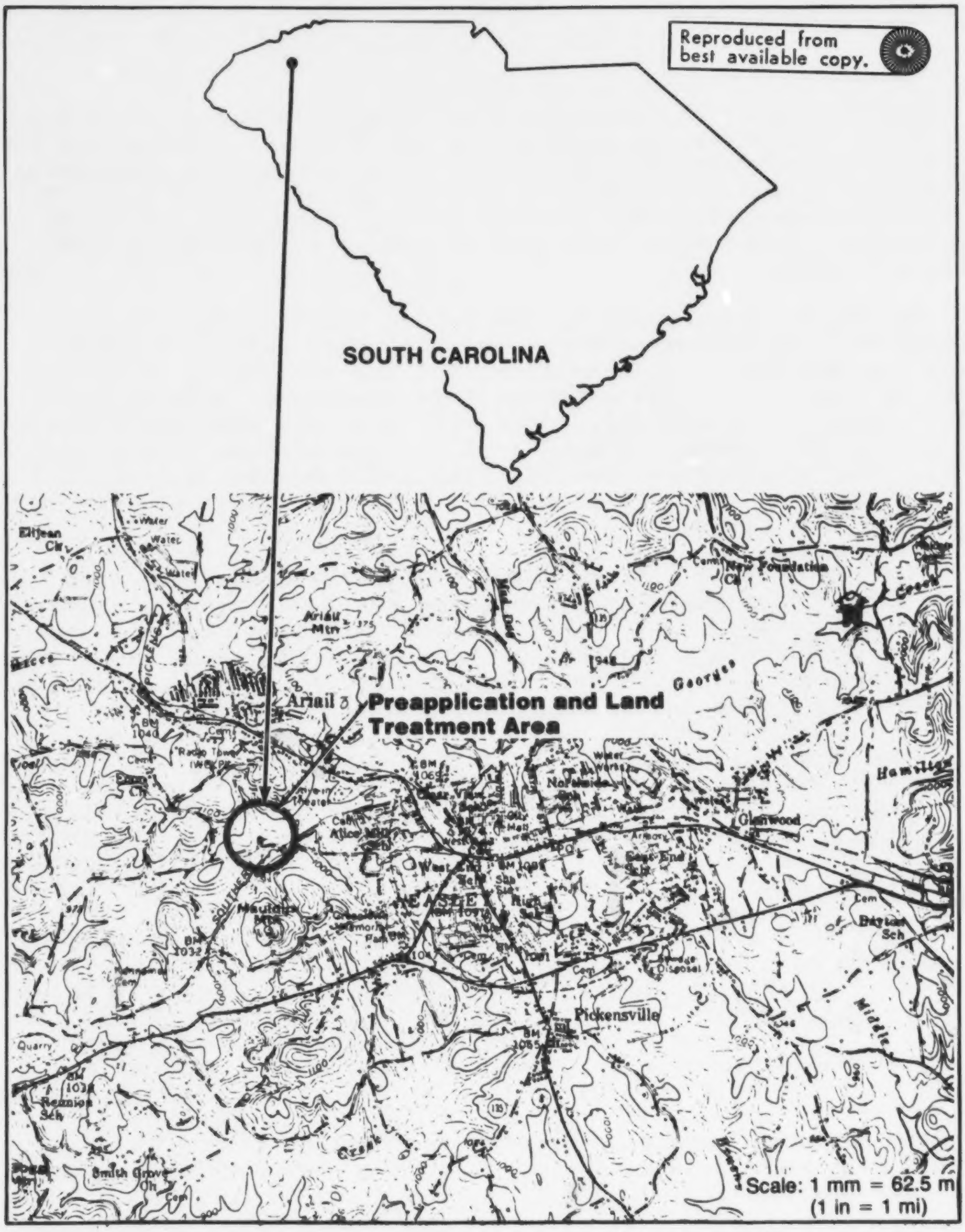

SOUTH CAROLINA
Preapplication and Land Treatment Area
Arial
Ariail Mtn
Eltjean Ch
New Foundation Ch
Georges
Hamilton
Glenwood
Norwood Sch
Alice Mill
West End Sch
Pickensville
Quarry
Reunion Sch
Smith Grove Ch
Middle
Creek
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-52. Location map of Easley combined utilities system Golden Creek overland flow project (# 018), Easley, South Carolina.

PHYSICAL FACILITIES

The Golden Creek oxidation pond is approximately 1.1 m (3.5 ft) deep, and covers an area of 3.6 ha (9 acres). Following the approximately 90-day detention time in the pond, the wastewater is pumped to the overland flow site by one of two 3.7-kw (5 hp) centrifugal nonclog pumps (Figure A-53). The pumps supply approximately 0.008 m^3/s (127 gpm) to the spray nozzles of the effluent plots.

As the existing sewer to the Golden Creek oxidation pond passed through the site of the overland flow system, a splitting box was built into the line, and the raw sewage could either be diverted to the overland flow system, or pass directly to the pond (Figure A-54). Once diverted, the raw sewage passes through a bar screen followed by a comminutor, and enters a wet well. One level-controlled vertical shaft nonclog 5.6-kw (7.5 hp) centrifugal pump delivers 0.006 m^3/s (93.3 gpm) to the raw overland flow plots.

A total of 17 plots are available at the Easley overland flow site. Of these, three plots are utilized for raw, comminuted wastewater, and 10 plots are for oxidation pond effluent. The other four plots are spares to be utilized during times when the oxidation pond plots are being dried prior to grass cutting. The raw plots measure 33.5 m (110 ft) wide by 53.3 m (175 ft) long. The oxidation pond plots, as well as the spare plots, measure 30.5 m (100 ft) wide by 45.7 m (150 ft) long. All plots are graded to a 4-percent slope. The total treatment area available is 2.5 ha (6.1 acres). The pond effluent plots can be automatically controlled by a timer connected to a series of electrically-operated solenoid valves which automatically water each plot.

All of the treated wastewater collected from the overland flow plots is collected in earthen ditches, combined, and diverted to an effluent chlorination system. The system is level actuated but is not flow proportional, and supplies gaseous chlorine at a constant, specified rate. The wastewater then flows through a flume with a continuous recorder, and out a paved swale prior to discharge to a tributary of Golden Creek.

The 17 plots were planted with Kentucky 31 fescue and rye grass. However, some native grasses have also developed. The site is underlain by a sandy clay soil.

As the system was designed and is operated as a full-scale research demonstration project, the loading rates are varied on different plots. All of the raw plots were hydraulically loaded at 23.6 mm/day (0.93 in/day), five days per week corresponding to 119 mm/wk (4.67 in/wk). Wastewater was applied for

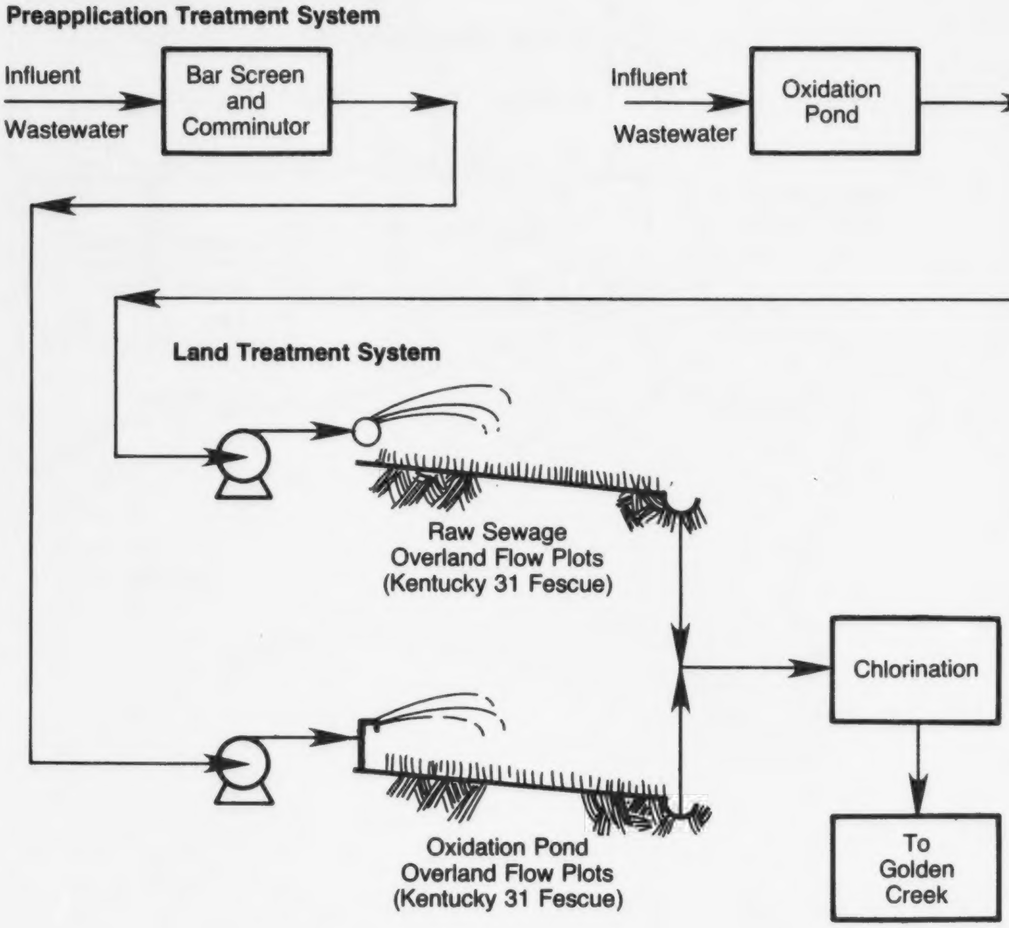

Preapplication Treatment System
Influent
Wastewater
Bar Screen and Comminutor
Influent
Wastewater
Oxidation Pond
Land Treatment System
Raw Sewage Overland Flow Plots (Kentucky 31 Fescue)
Chlorination
Oxidation Pond Overland Flow Plots (Kentucky 31 Fescue)
To Golden Creek

Figure A-53. Process flow diagram of Easley combined utilities system Golden Creek overland flow project (# 018), Easley, South Carolina.

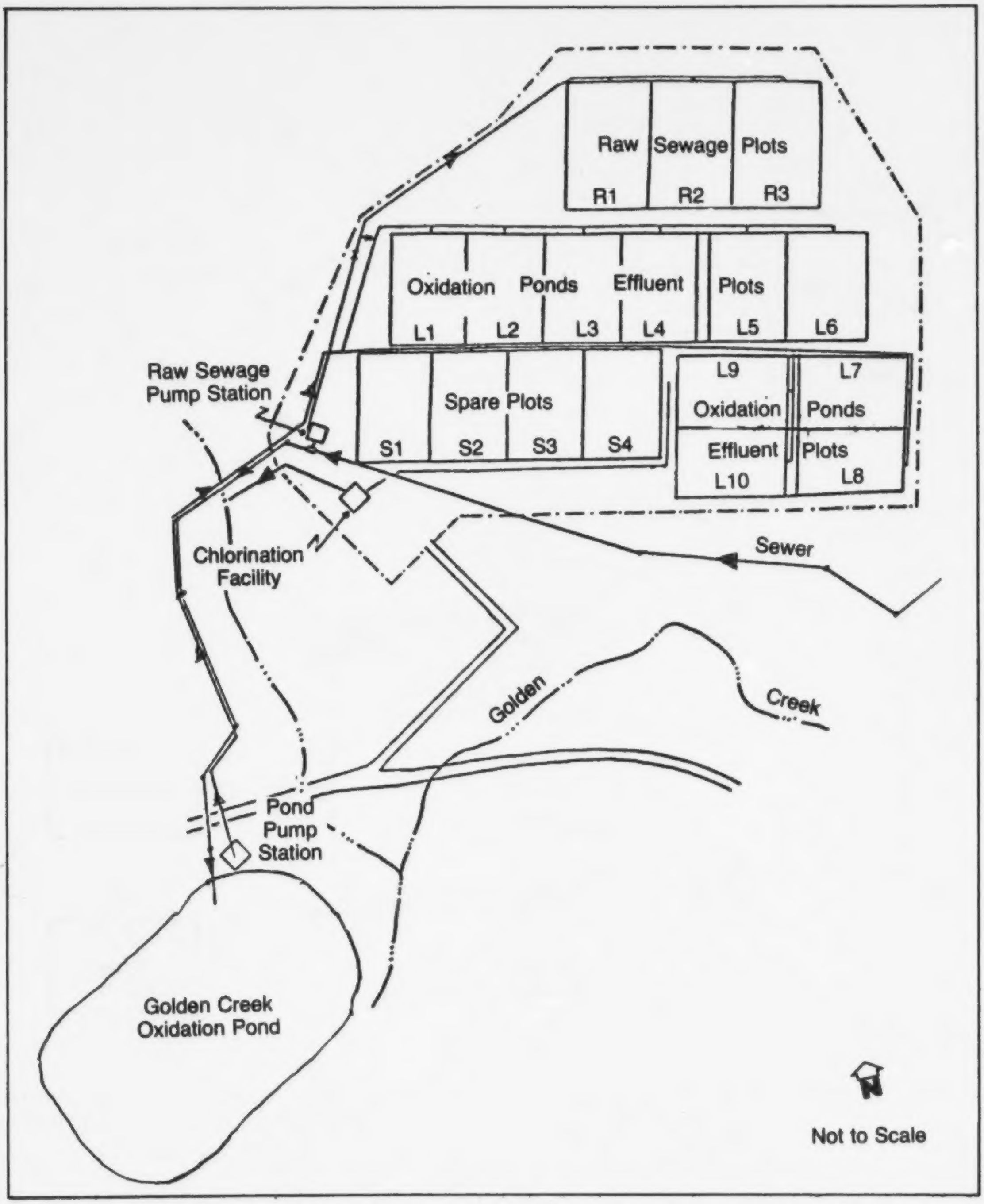

Raw Sewage Plots
R1
R2
R3
Oxidation Ponds Effluent Plots
L1
L2
L3
L4
L5
L6
Raw Sewage Pump Station
Spare Plots
S1
S2
S3
S4
L9
L7
Oxidation Ponds
Effluent Plots
L10
L8
Chlorination Facility
Sewer
Golden
Creek
Pond Pump Station
Golden Creek Oxidation Pond
N
Not to Scale

Figure A-54. Facility layout of Easley combined utilities system Golden Creek overland flow project (# 018), Easley, South Carolina.

six hours per day with an 18-hour rest period. The pond effluent plots were hydraulically loaded at 22.1 mm/day (0.87 in/day) for five days per week corresponding to from 103 mm/wk (4.06 in/week) to 193 mm/wk (7.60 in/wk). The application time varied from 5.5 hours per day to 8 hours per day. The four spare plots typically were not used. The following table presents organic and nutrient loadings:

	Comminuted Raw Sewage kg/ha/yr	Oxidation Pond Effluent kg/ha/yr
BOD_5	11,810	1,446-2,740
SS	10,982	3,098-5,871
T-P	172	64-121
TKN	1,718	220-420
NH_3-N	944	43-81
NO_3-N	80	28-53

As the system was originally designed, both the raw and oxidation pond wastewaters were to be sprayed onto the fields using low pressure fan nozzles, elevated 1.2 m (4 ft), approximately 5.1 m (16.6 ft) apart. The nozzles sprayed onto a crushed stone base (for erosion control and even distribution), and then onto the grass plots. Although the system was successful for the oxidation pond effluent, plugging problems forced the system to be abandoned in place of a different system. Two different methods of raw wastewater application have proved successful. In the first method, 0.15-m (6 in) PVC pipe with 51-mm (2 in) slots approximately 1.4 m (4.5 ft) apart is used to spread the water on the crushed stone. In the second method, 25-mm (1 in) open-ended PVC pipe is elevated 0.6 m (2 ft), and the water simply flows out the end onto the crushed stone. The pipes are the same distance apart as the initial nozzles (5.1 m (16.6 ft)).

Aside from the storage available in the Golden Creek oxidation pond (approximately 11,100 m^3 (2.9 mil gal), there is no additional storage. Five groundwater monitoring wells were installed in March 1980, however, no data were available at the time of the visit.

FACILITY OPERATIONS

The Golden Creek overland flow project is operated by the Easley Combined Utilities System, with technical help and guidance from Clemson University, Department of Environmental Systems Engineering.

The operation of the facility is simplified by the rigorous application program devised by the researchers at Clemson. In addition, the timer-controlled solenoid valves simplify the application schedule, especially since the oxidation pond effluent pumps are tied into the timer system. When the raw wastewater plots are to be irrigated, manual insertion and removal of a slide gate in the diversion structure is required.

The superintendent of the Golden Creek project, therefore, must only spend approximately four hours per day at the site. An additional 12 hours per week of a maintenance man's time is spent at the site, plus 12 hours per week for a summer employee who is mainly concerned with groundskeeping.

An outside contractor is used to cut and bale the hay from the plots. The hay is cut whenever it is about 0.46 m (18 in) to 0.61 (24 in) high. The cost of each cutting and baling is $200. The hay is currently used for construction site erosion control as the state has yet to approve it for animal feed. Typically, a three to four day dry-up time is allowed prior to cutting the hay.

Following hay cutting and baling, an operational problem exists due to hay being washed down the slopes and into the collection troughs. Once the hay reaches the chlorine contact tank, it may be drawn up through the eductor system, causing subsequent plugging. The frequency of plugging has been substantially reduced by installation of a screen prior to the contact tank.

A second operational problem is due to line clogging in the raw waste distribution system when the system is shut down. The problem is due to cellulose and cotton mill waste fibers which settle out and clog the line, necessitating line rodding. To solve this problem, the raw lines are flushed out with pond water whenever the system will be shut down for an extended period of time. The various fibers in the water also form a mat on the raw wastewater plots. This mat covers the first meter of the plot but causes no operational problems.

At the time of the site visit, the system was not operational as it had been shut down for hay removal. Due to the antecedent weather conditions, the grass was 0.9 m (36 in) high when cut, and the equipment left a substantial amount of tall grass on the field.

An additional operational problem is associated with the raw sewage wet well. Due to the long detention time in the wet well, solids settle out, causing pump plugging and odor problems. The situation has been alleviated by using only the bottom-sloped portion of the wet well, thereby decreasing the detention time.

The quality of the influent to and effluent from the overland flow plots is as follows:

	Raw Comminuted Wastewater	Oxidation Pond Effluent	Effluent from Raw Wastewater Plots	Effluent from Oxidation Pond Plots
BOD_5, mg/L	200	28	23	15
SS, mg/L	186	60	8	40
T-P as PO_4, mg/L	8.9	3.8	4.0	2.2
Ortho-P as PO_4, mg/L	6.6	3.0	3.8	1.7
TKN, mg/L	29.1	4.3	7.4	1.0
NH_3, mg/L	19.4	1.0	4.0	0.4
NO_3, mg/L	6.0	2.4	1.2	1.1

Based on Clemson University work (Abernathy, 1980), the oxidation pond overland flow plot quality was independent of application rate for the rates studied, and the raw wastewater overland flow plot effluent was comparable to conventional secondary treatment with respect to organic and solids removal, and better than secondary with regard to nutrient removal. Interestingly, the raw wastewater plots produced an effluent lower in suspended solids than the oxidation pond plots (8 mg/L vs 40 mg/L), which is believed due to the fact that the algae in the oxidation pond effluent are difficult to remove because of their small size.

FACILITY MAINTENANCE

General maintenance and housekeeping at the Golden Creek overland flow project site was good. All normal maintenance is done at the site by an Easley Combined Utilities System maintenance man. Approximately 12 hours per week are spent at the site. There are two major maintenance problems at the facility. The first of these is the treated wastewater collection ditches. The ditches are grass-lined to prevent erosion; however, the ditches are difficult to mow as they are always wet, causing rapid grass growth. Lining these channels with concrete was recommended by the plant operator.

A second maintenance problem has been the electrically-controlled solenoid valves in the valve pits used to automatically operate the oxidation pond plots. Owing to the damp environment, the solenoid valves have rusted, and therefore, failed. This situation is being corrected by the installation of sealed air-actuated valves.

OPERATION AND MAINTENANCE COSTS

A total budget of $28,659 has been allocated for the period 12 November 1979 to 11 November 1980 (this operation and maintenance budget does not include costs incurred by Clemson University personnel). The cost breakdown includes:

Personnel	$ 8,944
Fuel and electricity	2,200
Chemicals	1,440
Engineering services	3,000
Maintenance and repairs	3,995
Administration	6,000
Transportation	2,080
Land lease	1,000
Total	$28,659

An additional $10,211 of previous year's carryover money is being used for purchasing new air controlled valves, flow monitoring equipment, grass harvesting equipment, and a storage shed.

DESIGN DEFICIENCIES

Various design deficiencies exist at the Golden Creek overland flow site, many of which have been previously alluded to including:

1. Comminuted raw wastewater plugging spray nozzles.
2. Solenoid valves rusting, causing need for replacement.
3. Unlined treated water collection ditches.

4. Constant rate chlorination application only.

5. Grass clogging of chlorine eductor system.

6. Raw wastewater wet well oversized.

Additional design deficiencies include:

1. In-ground electrical wire to solenoid valves not placed in conduits.

2. In-ground PVC distribution piping connected to galvanized steel risers which break off at the PVC pipe when hit, necessitating digging up the pipe.

3. Insufficient time to allow for proper grass rooting prior to wastewater application.

The last design deficiency is important as wastewater which is applied too soon will cause erosion and subsequent poor wastewater distribution, causing poor treatment.

TOWN OF WAREHAM WATER POLLUTION CONTROL FACILITY (# 019)

WAREHAM, MASSACHUSETTS

RAPID INFILTRATION SYSTEM

GENERAL

The Town of Wareham, Massachusetts is located in southeast Massachusetts approximately 80 km (50 mi) southeast of Boston (Figure A-55). The Town of Wareham owns and operates both the wastewater treatment and rapid infiltration systems. The facility was visited on May 28, 1980.

The climate in the Wareham area is seasonal, with a yearly average temperature of 11.1°C (51.9°F). The yearly average precipitation is 1.0 m (39.77 in). The estimated yearly average Class A pan evaporation is 0.86 m (34 in).

The Town of Wareham Water Pollution Control Facility achieves secondary treatment by utilizing preliminary treatment followed by an activated sludge system (Figure A-56). Biologically-treated wastewater then flows to a rapid infiltration system comprised of eight beds covering an area of 1.62 ha (4 acres).

The facility was designed to handle 0.079 m^3/s (1.8 mgd). Current flows to the facility are averaging 0.014 m^3/s (0.32 mgd). The facility, therefore, is hydraulically loaded at 18 percent of its design hydraulic capacity. The plant receives approximately 18.9 m^3/day (5,000 gpd) of industrial waste from a fastener manufacturer.

The entire collection system, preapplication treatment system and rapid infiltration system, has been in operation for eight years. The site is located in a residential area. Future plans for the facility call for upgrading some of the preapplication treatment equipment. This equipment, however, will not materially affect the operation and maintenance of the land application portion of the system.

PHYSICAL FACILITIES

All wastewater arrives at the Wareham Water Pollution Control Facility by force main. As there are many pumping stations in town, the wastewater typically is septic.

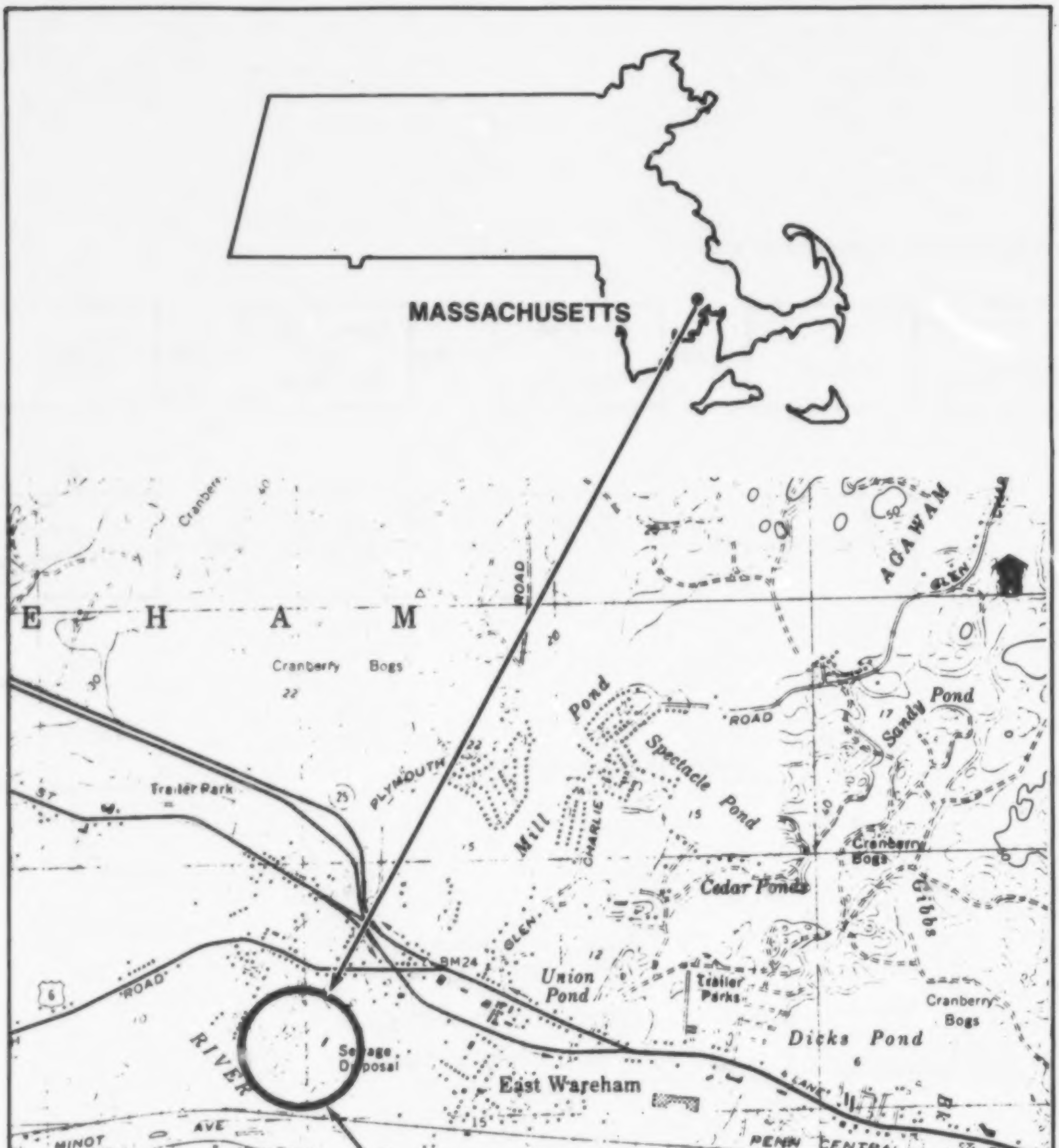

MASSACHUSETTS
E H A M
Cranberry Bogs
Trailer Park
PLYMOUTH
Mill Pond
Spectacle Pond
Sandy Pond
AGAWAM
ROAD
CHARLIE
Cedar Ponds
Cranberry Bogs
Gibbs
Union Pond
Trailer Parks
Dicks Pond
RIVER
Sewage Disposal
East Wareham
BM24
MINOT AVE
PENN CENTRAL
Minot Forest Sch
Brandy Hill
Beaverdam Pond
Gravel Pit
Cranberry Bog
Preapplication and Land Treatment Area
Muddy Cove
Riverside
Broad Cove
Scale: 1 mm = 25 m
(1 in = 2,100 ft)

Figure A-55. Location map of Town of Wareham water pollution control facility (# 019), Wareham, Massachusetts.

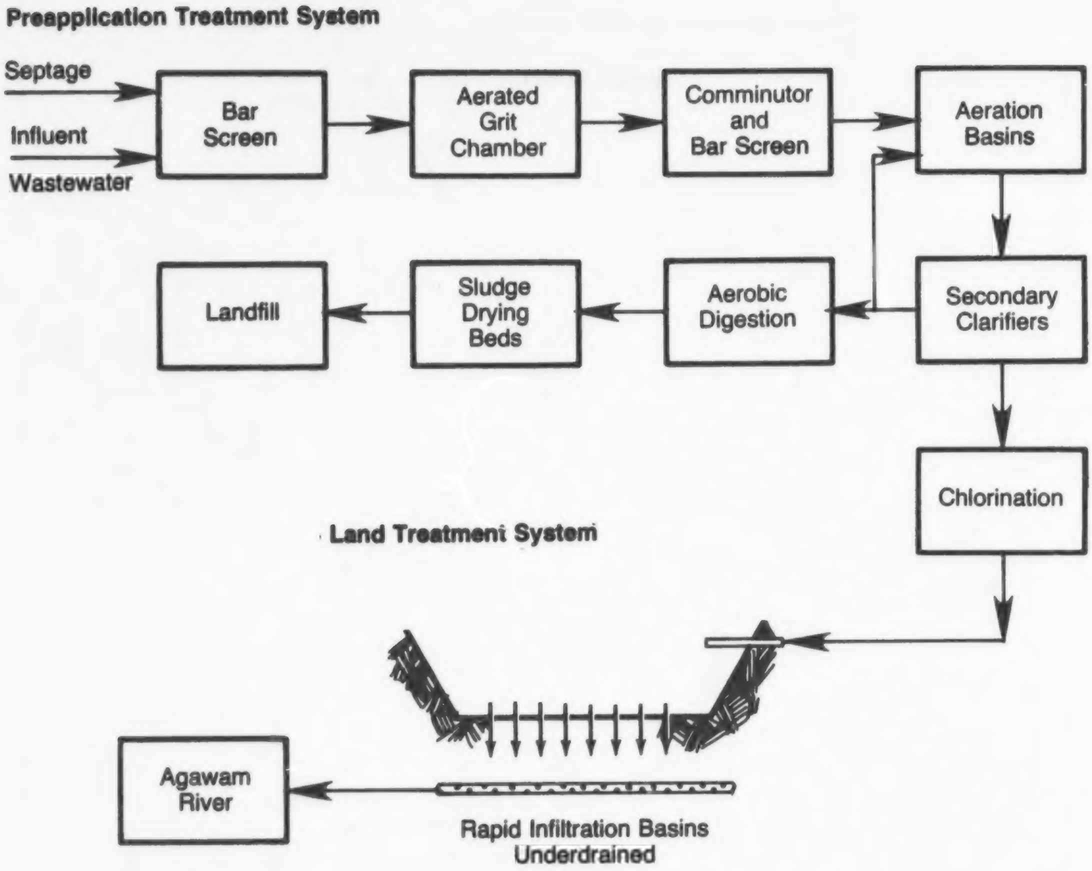

Preapplication Treatment System
Septage
Influent
Wastewater
Bar Screen
Aerated Grit Chamber
Comminutor and Bar Screen
Aeration Basins
Secondary Clarifiers
Aerobic Digestion
Sludge Drying Beds
Landfill
Chlorination
Land Treatment System
Agawam River
Rapid Infiltration Basins Underdrained

Figure A-56. Process flow diagram of Town of Wareham water pollution control facility (# 019), Wareham, Massachusetts.

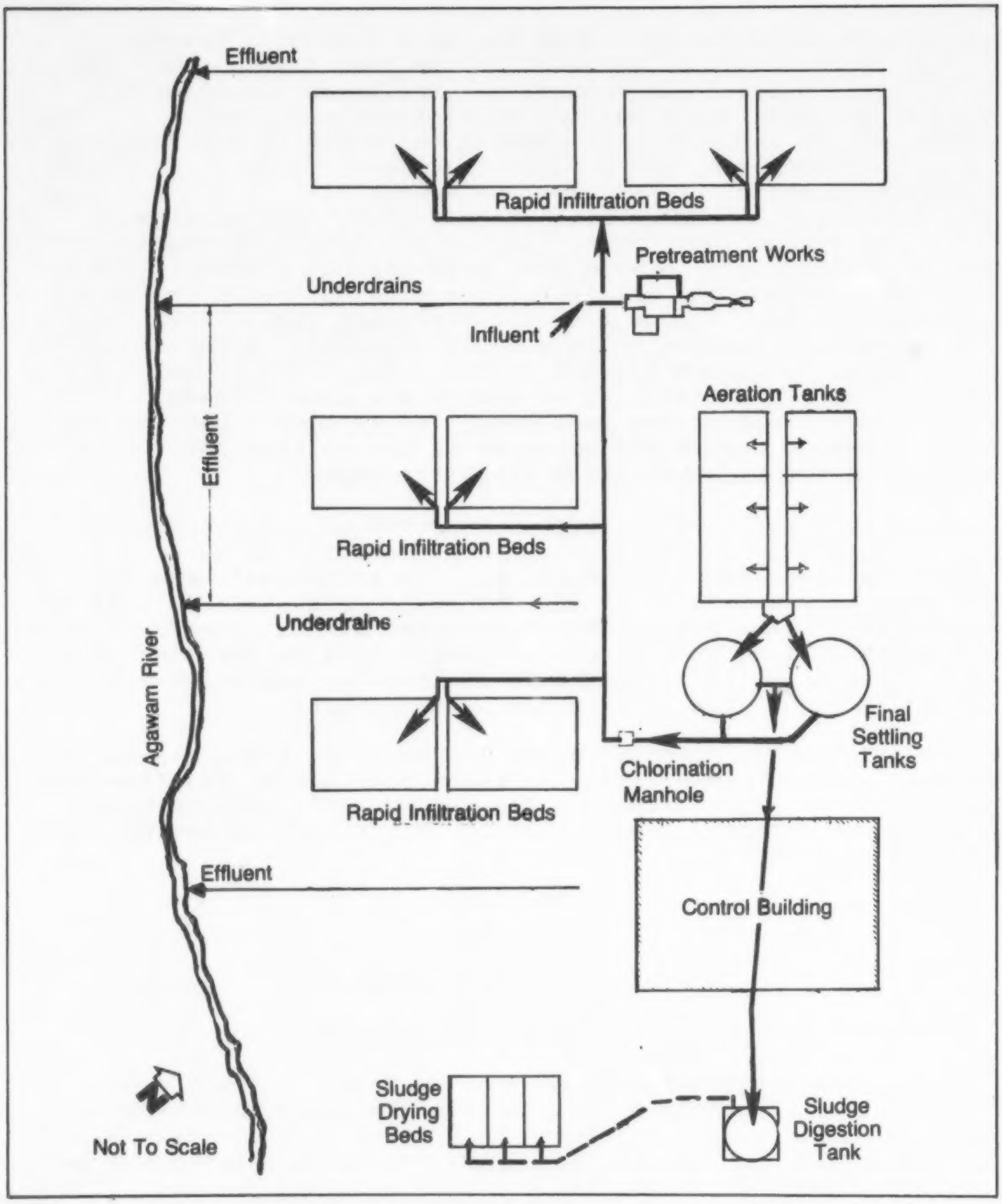
Hydrogen peroxide has been used for odor control. However, caustic is currently being added to the pump stations and the preapplication treatment headworks. Preliminary treatment consists of a hand-cleaned bar screen followed by an aerated grit chamber with mechanical grit removal, a second hand-cleaned bar screen, a comminutor, and a Parshall flume. There is no primary treatment at the plant, and the wastewater next flows directly into four aeration basins with fixed surface mechanical aerators. The mixed liquor then flows to two secondary clarifiers. From this point, the forward flow goes through a manhole where chlorine is added. At this point the water proceeds to the land treatment system. Sludge from the secondary clarifiers is either recycled or wasted to an aerobic digester. After digestion, sludge is pumped to sand drying beds, and then is landfilled. Secondary clarifier skimmings are also pumped to sand drying beds. Sand drying beds percolate is pumped back to the plant. Septage wastes are accepted at the initial bar screen facility in the preapplication treatment works.

The rapid infiltration system consists of eight percolation beds (Figure A-57). The physical configuration is such that each of two beds is piped together. The individual beds are 30.5 m by 67.1 m (100 ft by 220 ft) for a total area of 1.62 ha (4.0 acres). Within each bed, wastewater is distributed by means of a slotted flume made of plywood which lies on the base of the basin. The flume is connected to an influent box which overflows into the trough. The soil in the beds is sand.

Aside from any standing water in the beds, there are no additional storage capabilities at these facilities, and flow that comes into the plant displaces flow to the infiltration beds. Based on the current flow rate at the plant, the following loadings are in effect:

Hydraulic	27.1 m/yr 2.1 m/wk
Organic	4,103 kg BOD_5/ha/yr
Solids	5,471 kg SS/ha/yr

There are no groundwater monitoring wells in the vicinity of the facility. There is no runoff from the rapid infiltration beds. The entire site is fenced to control site access. A buffer zone of 30.5 m (100 ft) as a minimum exists between the beds and the neighboring properties.



Effluent
Rapid Infiltration Beds
Pretreatment Works
Underdrains
Influent
Aeration Tanks
Effluent
Rapid Infiltration Beds
Underdrains
Agawam River
Final Settling Tanks
Chlorination Manhole
Rapid Infiltration Beds
Effluent
Control Building
N
Not To Scale
Sludge Drying Beds
Sludge Digestion Tank

Figure A-57. Facility layout of Town of Wareham water pollution control facility (# 019), Wareham, Massachusetts.

All of the infiltration beds are underdrained with open joint concrete pipe approximately 2.4 m (8 ft) below the surface of the bed. The concrete pipe is surrounded by graded stone. Four underdrain systems exist, one for each set of two beds. The underdrains discharge to the Agawam River.

FACILITY OPERATIONS

Due to the low hydraulic loading of the plant, the two smaller aeration basins are not in service and only the two larger basins are being used. In addition, only one of the two final clarifiers is in service. Effluent quality from the facility is of secondary quality containing 15 mg/L BOD_5 and 20 mg/L SS.

The land treatment system is operated continuously 24 hours per day, seven days per week. Typical operation consists of applying the chlorinated effluent to two basins continuously until approximately 0.3 m (12 in) of standing water is in the bed. Depending on the physical condition of the bed, this will usually take approximately one week as a minimum. After there is standing water in the bed, the bed is taken off-line and another bed is put in service.

Typically, it takes approximately three weeks for the water to infiltrate and the bed to dry completely prior to additional applications of water.

Only one operational problem was noted during the visit. The underdrain system is located below the high tide level of the Agawam River, and during various parts of the tide cycle, effluent samples from the rapid infiltration bed underdrains cannot be collected.

Limited staffing is required to operate the infiltration beds. Slightly over one hour per day is necessary for operation of the system.

FACILITY MAINTENANCE

The overall plant maintenance appeared good, and there were no apparent maintenance problems. As opposed to other rapid infiltration systems, the Wareham facility does little in the way of working the beds. In fact, of the eight beds, four were just recently cleaned. The cleaning consisted of using a bulldozer to remove the first 0.15 m (6 in) of sand. Provisions are currently being made to do the same with the other four beds as they have some sludge deposits at the surface. Following the cleaning operation, the beds operate much better. The only other maintenance performed on the beds was done a few years ago when the beds were raked, but none of the sand was ever removed.

In the eight years the facility has been in operation, the plywood flumes used for distributing the wastewater have never been repaired. During the site visit, the Town of Wareham was in the process of refurbishing some of the plywood flumes which were falling apart.

OPERATION AND MAINTENANCE COSTS

A total of $138,000 was spent in fiscal year 1979-1980 for operation and maintenance at the Wareham Water Pollution Control Facility, with approximately 50 percent of this money being spent on labor. The land treatment portion of the budget was estimated to cost only $1,380 in salaries.

DESIGN DEFICIENCIES

Only one design deficiency was noted during the visit. This involved improper location of the outfalls in terms of the tidal cycle of the Agawam River.

CHATHAM WATER POLLUTION CONTROL FACILITY (# 020)

CHATHAM, MASSACHUSETTS

RAPID INFILTRATION SYSTEM

GENERAL

Chatham, Massachusetts is located in the southeastern portion of Cape Cod on the Atlantic Ocean (Figure A-58). Both the wastewater preapplication treatment facility and the land treatment facility are owned and operated by the Town of Chatham. The facility was visited on May 29, 1980.

The Chatham area has a seasonal climate, with a yearly average temperature of 9.7°C (49.4°F). The average annual precipitation is 1.1 m (43.35 in), whereas the mean annual Class A pan evaporation is 0.81 m (32 in). Due to the sea breezes in the area, it is somewhat cooler than the mainland during the summer, and is a popular resort area as is the whole of Cape Cod.

The preapplication treatment at Chatham consists of preliminary treatment followed by activated sludge biological treatment (Figure A-59). The effluent from the activated sludge flows by gravity to one of four rapid infiltration beds. The beds contain a total of 1.54 ha (3.8 acres).

The Chatham facilities were designed for a flow of 1,666 m^3/day (0.44 mgd). The current flows average 397 m^3/day (105,000 gpd) during the summer, and 208 m^3/day (55,000 gpd) during the winter months. Therefore, the plant is, at most, loaded at only 24 percent of its design hydraulic loading. The plant receives only domestic wastewater. However, tourists and tourist-related industries also contribute to the system.

The Chatham wastewater treatment facilities have been in operation for nine years. The land use adjacent to the plant is basically rural residential. There are no future plans for modifications or changes at the Chatham facility.

PHYSICAL FACILITIES

All wastewater is pumped to the treatment facilities. At the plant the wastewater is subjected to preliminary treatment,

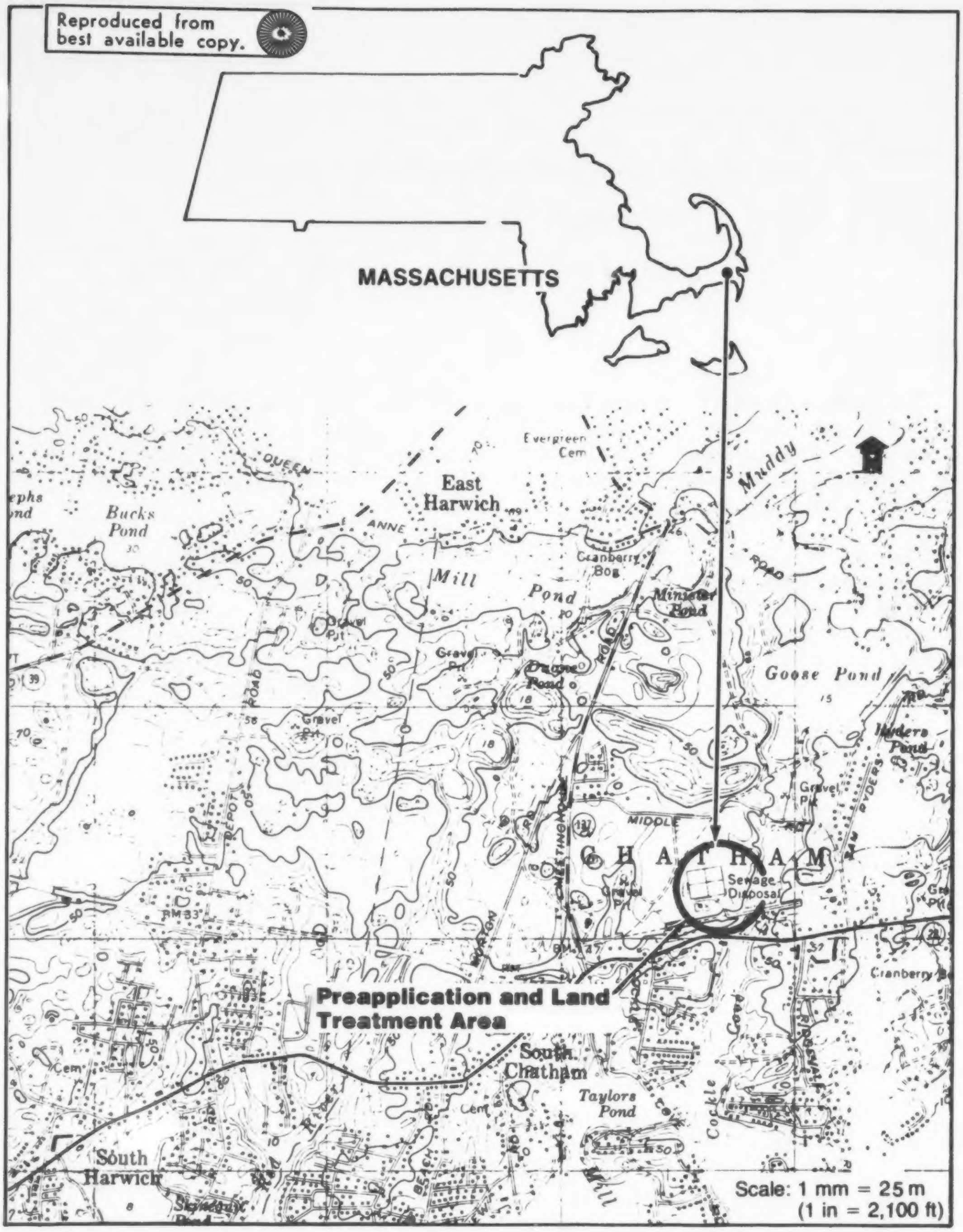

Reproduced from best available copy.
MASSACHUSETTS
East Harwich
Evergreen Cem
Bucks Pond
Mill Pond
Cranberry Bog
Minister Pond
Goose Pond
Gravel Pit
CHATHAM
Sewage Disposal
Preapplication and Land Treatment Area
South Chatham
Taylors Pond
South Harwich
Cockle Cove
Scale: 1 mm = 25 m
(1 in = 2,100 ft)

Figure A-58. Location map of Chatham water pollution control facility (# 020), Chatham, Massachusetts.

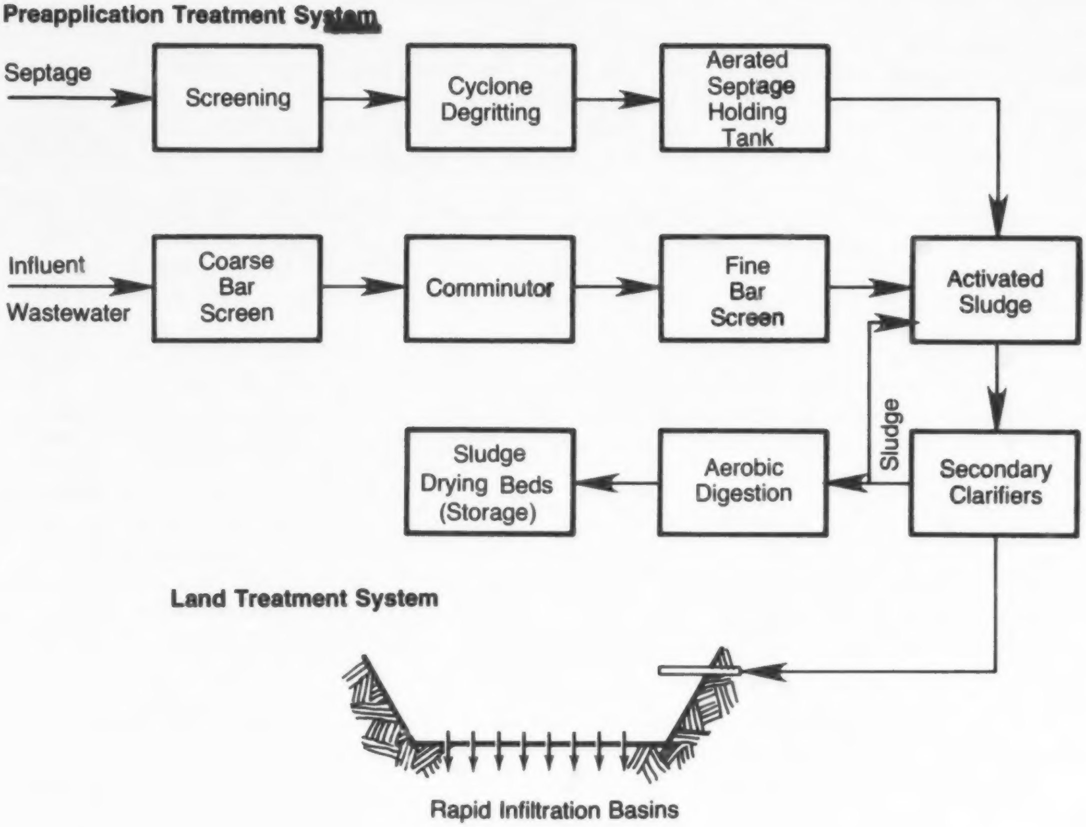

Preapplication Treatment System
Septage
Screening
Cyclone Degritting
Aerated Septage Holding Tank
Influent Wastewater
Coarse Bar Screen
Comminutor
Fine Bar Screen
Activated Sludge
Sludge
Secondary Clarifiers
Aerobic Digestion
Sludge Drying Beds (Storage)
Land Treatment System
Rapid Infiltration Basins

Figure A-59. Process flow diagram of Chatham water pollution control facility (# 020), Chatham, Massachusetts.

consisting of a coarse bar rack followed by a comminutor, fine bar screen, and flow measurement utilizing a Parshall flume. The wastewater then flows into an activated sludge unit. The overflow from the two activated sludge basins flows to two secondary clarifiers. The effluent overflows the clarifiers into a distribution manhole, ultimately flowing to one of four rapid infiltration beds (Figure A-60) without chlorination.

Septage is also received at the facility. The septage is first dumped through a bar screen into a holding tank, then proceeds through grit removal to aeration in a converted aeration tank. After aeration, the septage is fed, at a controlled rate of 5 percent of the forward flow, to the activated sludge basins.

Sludge from the secondary clarifiers flows to an aerobic digester. Following digestion, sludge is pumped through a portable hose to one of the four rapid infiltration beds which is currently being utilized as the sludge drying and storage area.

The beds are 54.9 m by 70.1 m (180 by 230 ft) each in size. The total area covered by the beds is 1.54 ha (3.8 acres). The wastewater distribution system consists of two diversion structures with control gates which can divert the wastewater to either of two percolation beds. Within each one of the percolation beds, there are two standpipes through which the wastewater overflows and spreads out into the basin. A certain amount of vegetation is currently growing in the beds. The rapid infiltration beds are constructed of natural sand. The berm walls are approximately 1.8 m (6 ft) high. The side slopes of the beds are covered with crushed stone for erosion protection. A ramp is contained in each bed for equipment access.

The loading rate at the Chatham facility is as follows (based on only one bed in operation):

Hydraulic	28.8 m/yr
(winter)	0.38 m/wk
(summer)	0.72 m/wk
Organic	5,616 kg BOD_5/ha/yr
Solids	4,405 kg SS/ha/yr

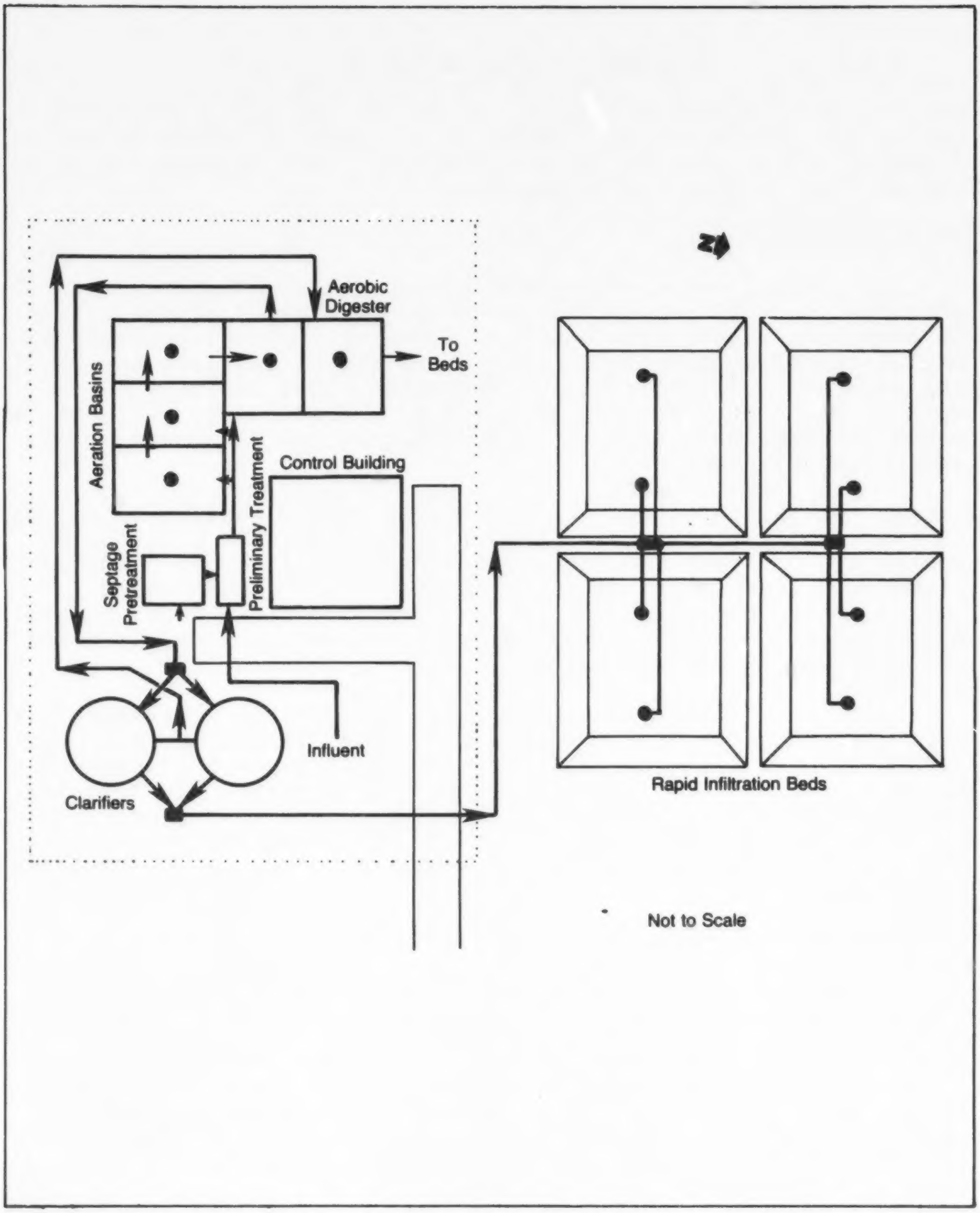

Aerobic Digester
To Beds
Aeration Basins
Preliminary Treatment
Control Building
Septage Pretreatment
Influent
Clarifiers
N
Rapid Infiltration Beds
Not to Scale

Figure A-60. Facility layout of Chatham water pollution control facility (# 020), Chatham, Massachusetts.

There are no groundwater monitoring wells in the vicinity of the Chatham facility. Although access to the treatment plant is controlled by means of a fence, access to the rapid infiltration system is not controlled. There is no runoff from the facility. A wooded buffer zone of 305 m (1,000 ft), as a minimum, is maintained from neighboring properties.

FACILITY OPERATIONS

The preapplication treatment system has been modified in the past few years by converting one of the activated sludge basins to a septage preaeration facility. One of the activated sludge basins is still empty owing to the low flows, and only one of the secondary clarifiers is in operation. The facility in general operates efficiently, as shown by the secondary effluent it produces which has 19.5 and 15.3 mg/L BOD_5 and suspended solids, respectively.

The operation of the land treatment system is simplified due to the low flow received at the facility. For the past three years, all effluent from the treatment facilities has been disposed of in one rapid infiltration bed. Once a week the discharge point in the bed is switched from one side to the other. A second rapid infiltration bed is currently being utilized for sludge dewatering and storage.

In terms of operation, there were no problems expressed, except that the State of Massachusetts Water Quality Board is disturbed by the weeds growing in the beds and wants them removed. Since there is a lack of plant personnel, however, the beds are not being cleaned of weed growth. Of the total time spent at the plant by the operating personnel, approximately three hours per week are spent operating and maintaining the rapid infiltration beds.

FACILITY MAINTENANCE

The maintenance of the entire preapplication treatment system appeared good. The rapid infiltration beds were adequately maintained except for the weeds growing in them which should have little or no detrimental effect on operations, especially at the low flows the plant is currently receiving. Approximately two years ago, one of the infiltration beds was cleared of weeds. As it cost the town approximately $1,200 in labor, and the reason, or the need, for removing the weeds was not apparent, it is currently not being done.

OPERATION AND MAINTENANCE COSTS

A total of $78,580 was spent during fiscal year 1979-1980 on facility operation and maintenance. Of this total, 3 percent, or $2,115 was spent on land treatment, the expense being associated with the labor required for the infiltration beds.

DESIGN DEFICIENCIES

Only one design deficiency was noted during the plant visit -- the infiltration beds are not fenced in to control public access.

TOWN OF BARNSTABLE WATER POLLUTION CONTROL FACILITY (# 021)

HYANNIS, MASSACHUSETTS

RAPID INFILTRATION SYSTEM

GENERAL

The Town of Barnstable is located in the southeast portion of Massachusetts on Cape Cod (Figure A-61). The Town of Barnstable contains the Hyannis portion of Cape Cod. The wastewater treatment and land application facilities are both owned and operated by the Town of Barnstable. The site was visited on May 30, 1980.

The climate of the Barnstable area is seasonal with a yearly average temperature of 11.1°C (51.9°F). Average annual precipitation is 1.0 m (39.77 in). The estimated mean annual Class A pan evaporation is 0.86 m (34 in).

The Town of Barnstable Water Pollution Control Facility is currently undergoing major upgrading and expansion. At the time of the visit, the secondary treatment facility had just come online. This report will only cover the system which has been in operation for many years, however. The wastewater preapplication treatment facilities at the plant consist of preliminary treatment followed by primary sedimentation. The primary treated wastewater then flows to one of six rapid infiltration beds which cover a total area of 3.24 ha (8 acres) (Figure A-62). With various modifications over the years, the plant is designed to handle 0.044 m^3/s (1 mgd). Due to the tourists and seasonal nature of the Cape Cod area, summer flows typically average 0.033 m^3/s (0.75 mgd), whereas winter flows average 0.018 m^3/s (0.40 mgd). The flow is basically domestic; however, it includes wastewater generated by the many restaurants in the vicinity of Barnstable. Septage is also received at the facility.

Wastewater has been treated at the site by the primary treatment and rapid infiltration systems for approximately 45 years. The system has been enlarged and expanded several times during this period. The current plans for the facility call for upgrading the plant to secondary treatment, utilizing activated

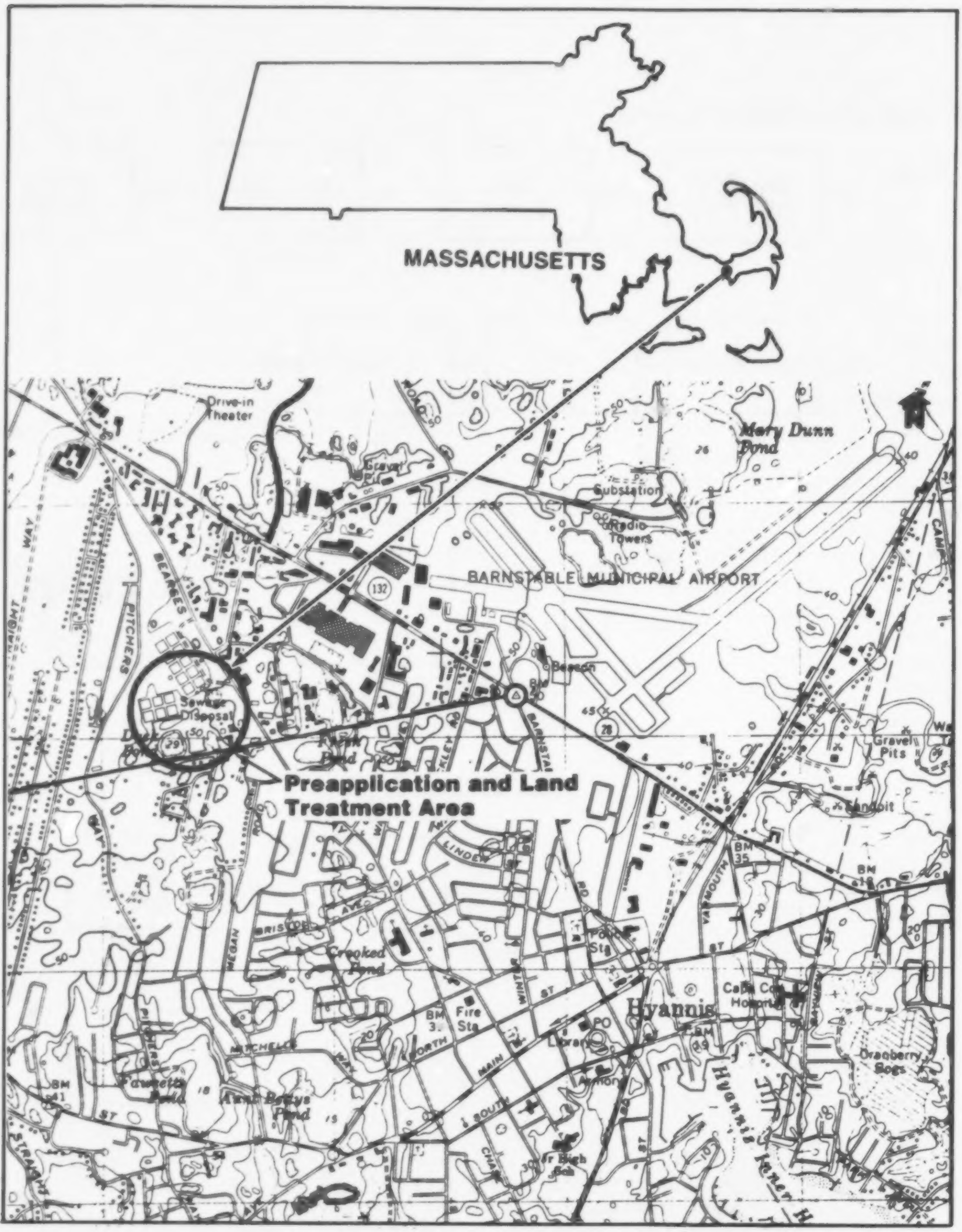
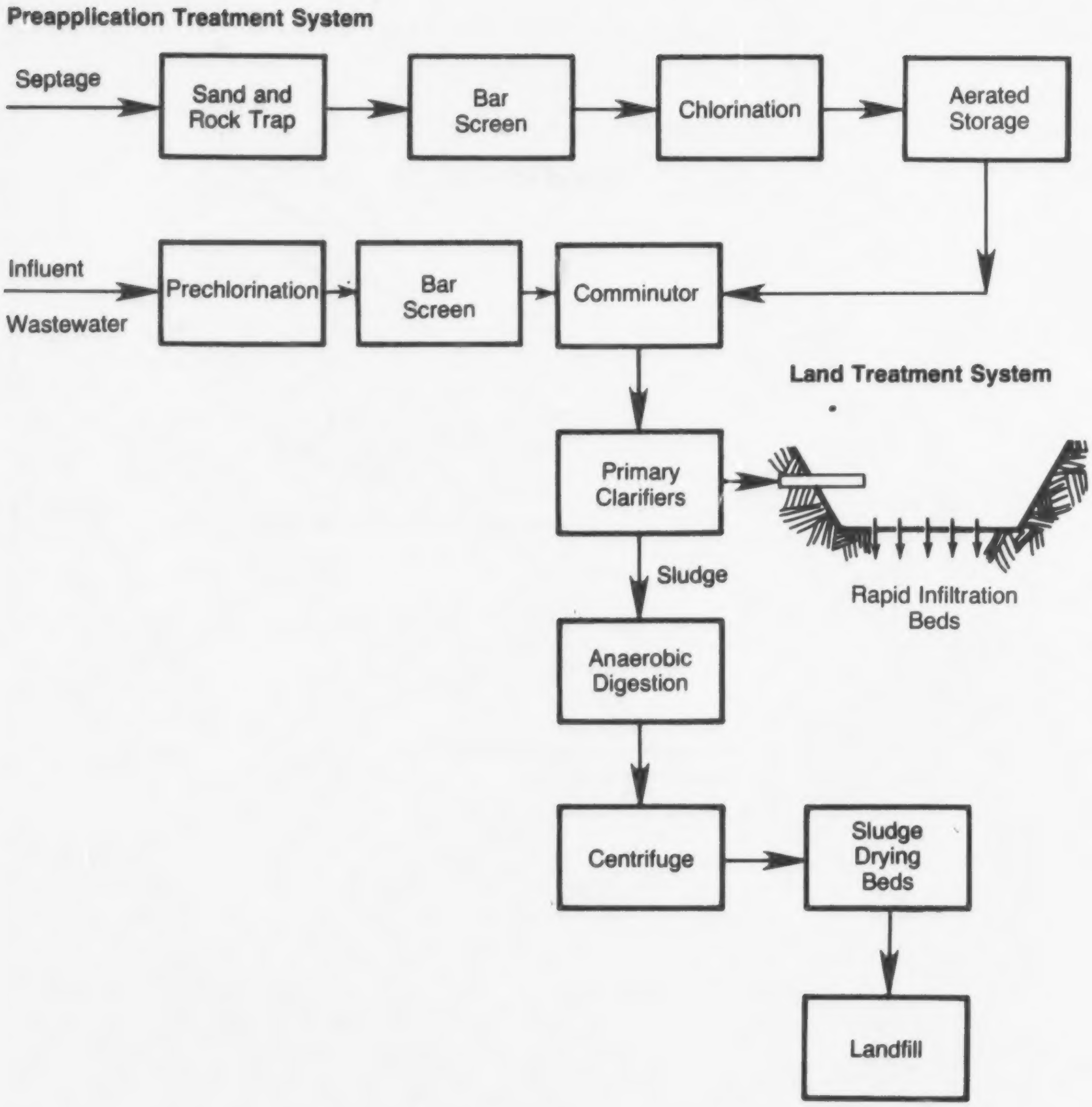

MASSACHUSETTS
Preapplication and Land Treatment Area
Sewage Disposal
BARNSTABLE MUNICIPAL AIRPORT
Drive-in Theater
Mary Dunn Pond
Substation
Radio Towers
Gravel Pits
Crooked Pond
Hyannis
Fire Sta
PO
Library
Armory
Police Sta
Cape Cod Hospital
Cranberry Bogs
Hyannis Harbor
132
28

Figure A-61. Location map of Town of Barnstable water pollution control facility (# 021), Hyannis, Massachusetts.



Preapplication Treatment System
Septage
Sand and Rock Trap
Bar Screen
Chlorination
Aerated Storage
Influent
Wastewater
Prechlorination
Bar Screen
Comminutor
Land Treatment System
Primary Clarifiers
Rapid Infiltration Beds
Sludge
Anaerobic Digestion
Centrifuge
Sludge Drying Beds
Landfill

Figure A-62. Process flow diagram of Town of Barnstable water pollution control facility (# 021), Hyannis, Massachusetts.

sludge followed by chlorination. The wastewater will then be automatically controlled and applied to 49 rapid infiltration beds which cover approximately 9.9 ha (24.5 acres).

The design flow for the upgraded wastewater treatment and land application facility is 0.18 m^3/s (4.2 mgd). Land use adjacent to the land application facility is both residential and commercial.

PHYSICAL FACILITIES

The preapplication treatment consists of preliminary treatment followed by primary treatment. Wastewater from the Barnstable area is pumped to the treatment plant where it is prechlorinated and goes through preliminary treatment consisting of bar screens followed by comminution. The wastewater then flows to two primary clarifiers, then to six rapid infiltration beds. Sludge from the primary clarifier goes to a single-stage standard rate anaerobic digester (unheated). Sludge is then dewatered in a centrifuge, further dewatered in a drying bed, and ultimately disposed of in a landfill. Skimmings from the primary clarifier are taken to the sludge drying beds.

The land treatment system consists of 16 beds approximately 0.20 ha (1/2 acre) each for a total area of 3.24 ha (8 acres) (Figure A-63). The beds receive water from the primary treatment facilities by gravity flow. The beds are filled with sand, some of it being natural. Over the years, some of the sand has been removed and replaced by imported sand.

Wastewater is distributed within the beds by an inlet structure which is a concrete headwall encasing the pipe which discharges to a pile of rocks used for erosion control. The average hydraulic application rate to the beds is 12.0 m/yr (39.3 ft/yr). Due to the variable application schedule for the bed dosing, a weekly application rate cannot be calculated.

Aside from any storage inherent in the rapid infiltration beds themselves, there is no storage. There are no groundwater monitoring wells at the facility (nine groundwater monitoring wells have been installed in conjunction with the new facilities). A minimum 30.5-m (100 ft) buffer zone surrounds the facility. Site access is controlled by a fence around the entire site. There is no runoff from the infiltration beds as they are bermed.

FACILITY OPERATIONS

The operation of the preapplication treatment system is fairly simple as it consists of preliminary and primary treatment, and therefore, does not materially affect the operation of

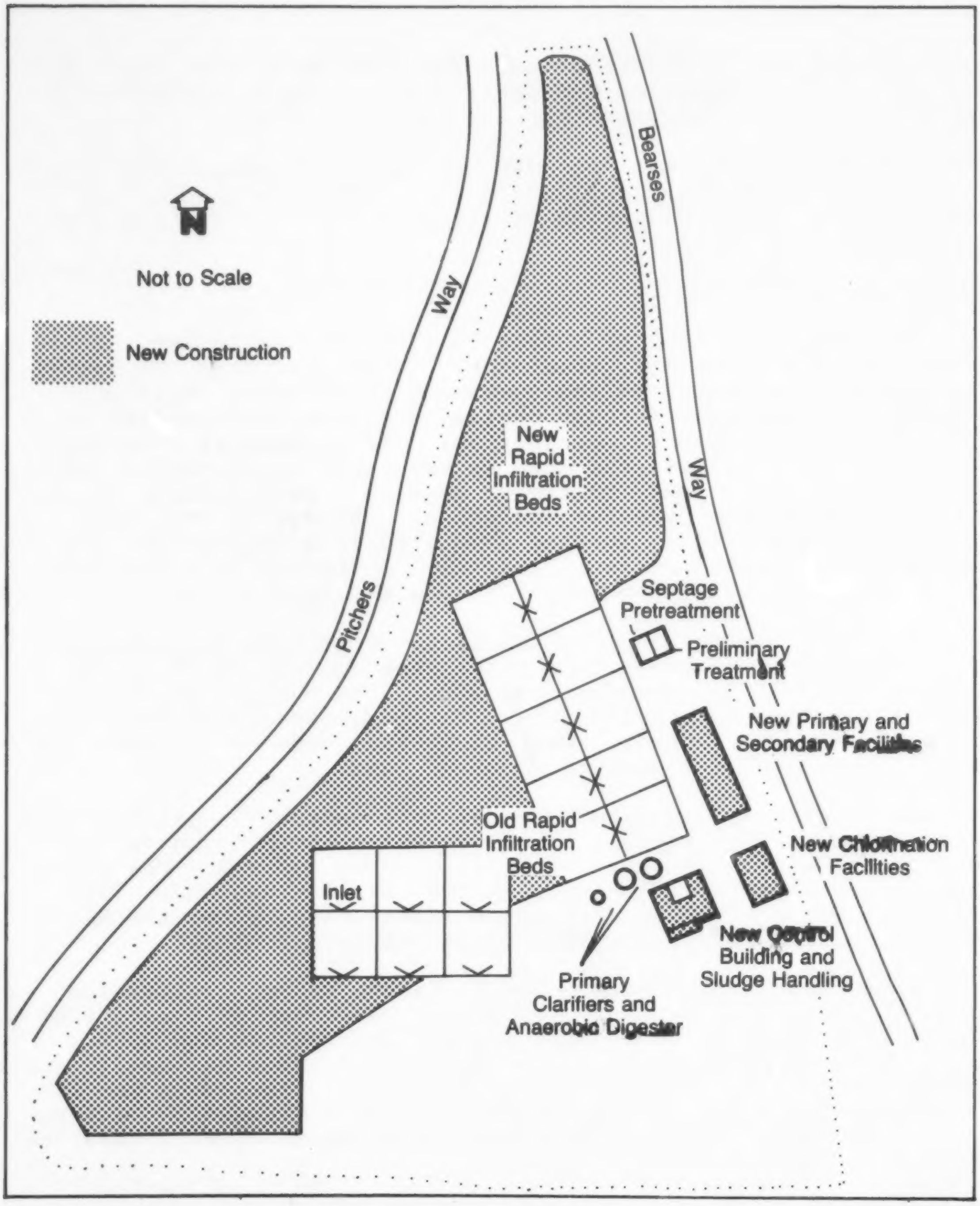

N
Not to Scale
New Construction
Bearses
Way
Pitchers
Way
New Rapid Infiltration Beds
Septage Pretreatment
Preliminary Treatment
New Primary and Secondary Facilities
Old Rapid Infiltration Beds
New Chlorination Facilities
Inlet
New Control Building and Sludge Handling
Primary Clarifiers and Anaerobic Digester

Figure A-63. Facility layout of Town of Barnstable water pollution control facility (# 021), Hyannis, Massachusetts.

the land treatment system. The fact that septage is accepted at the facility causes a major operational problem, however. This is due to the fact that the large number of restaurants in the Barnstable/Hyannis area pump not only septage waste, but also grease trap wastes to the "honeywagons." When the waste reaches the treatment plant it is screened, chlorinated, aerated, and treated with polymers, prior to addition to the primary clarifiers. The majority of the grease passes through the primary treatment facilities, however, and ends up in the rapid infiltration beds. In fact, the sand has been replaced several times in the beds and grease has been shown to have penetrated 1.8 m (6 ft) into the beds as shown by a test pit which was recently excavated. Prior to 1975 and the addition of the septage treatment facility, the primary effluent caused the expected operational problems in terms of surface plugging. This problem was solved by means of scarifying the beds, as will be discussed later. The problem of grease sealing the beds cannot be solved by scarifying the beds, however.

Typical operation of the rapid infiltration beds consists of dosing beds as required. This typically requires that two beds be dosed continuously for one day prior to the wastewater being applied to another bed. There is no strict schedule for deciding which bed is utilized, and rotation is based on visual inspection. Of the total staff of five workers (not including the plant superintendent), approximately 50 percent of their total time is spent at the treatment plant. Of this time, approximately 20 percent is associated with operation and maintenance of the rapid infiltration system.

FACILITY MAINTENANCE

At the time of the visit, the old primary facilities were being taken out of service as the new secondary facilities were being put on-line. Therefore, it is not possible to comment on the overall maintenance of the treatment facilities.

Prior to 1975 and the acceptance of septage at the treatment plant, maintenance of the infiltration beds consisted of scarifying the beds following each wastewater application. The scarifier was an 8-tooth device which was effective in breaking up the top 0.2 m (8 in) of the bed. In addition, approximately every 12 years the top 1.2 to 1.5 m (4 to 5 ft) of the bed would be removed by a bulldozer and replaced with new sand. After 1975, even scarification of the beds was not enough to keep the beds operational due to grease clogging. In conjunction with the plant upgrading, an additional 33 beds were installed, and the 16 older beds were refurbished. These new beds which have been used were also plugged by oil and grease, and provisions are currently being made to clean the beds.

Operationally, it is hoped that addition of the secondary treatment facilities will minimize the plugging problem. It should be stressed that plant personnel have attempted to stop the cartage of oil and grease with the septage. Due to local board of health rules, however, they have been unsuccessful. The treatment plant staff was of the opinion that, operationally, primary effluent can be applied to rapid infiltration beds, however, the oil and grease actually make the system unworkable.

OPERATION AND MAINTENANCE COSTS

For fiscal year 1976, a total of $79,275 was spent on the wastewater and land application systems. Of this expenditure, approximately 21 percent or $17,025 was associated with land application. The breakdown for the land application operation and maintenance is as follows:

Personnel	$ 9,900
Maintenance and repairs	4,875
Equipment purchase	375
Vehicles and tractors	1,875
Total	$17,025

DESIGN DEFICIENCIES

Plant operational personnel felt that there were basically no design deficiencies aside from the oil and grease problem. If the amount of oil and grease that would be received at the facility had been anticipated in 1975, then provisions for their removal from the septage could have been made. It is not known whether the engineers anticipated such an oil and grease loading at the time.

KENDAL/CROSSLANDS LAGOON SYSTEM (# 022)

KENNETT SQUARE, PENNSYLVANIA

SLOW-RATE SYSTEM

GENERAL

The Kendal/Crosslands Lagoon System serves two retirement communities in Kennett Square, Pennsylvania. Kennett Square is located approximately 48.3 km (30 mi) southwest of Philadelphia in the southeastern portion of Pennsylvania (Figure A-64). The system is owned and operated by the Kendal/Crosslands Association. The facility was visited on June 3, 1980.

The climate in the Kennett Square area is characterized by seasonal temperatures and the annual average temperature is 11.9°C (53.4°F). The yearly average precipitation is 1.10 m (43.13 in), whereas the mean annual Class A pan evaporation is 1.19 m (47 in).

The preapplication treatment system at the Kendal/Crosslands Lagoon System consists of an aerated pond, an oxidation pond, and a polishing pond, all in series (Figure A-65). Polishing pond effluent is chlorinated and pumped to the spray irrigation site. The slow-rate spray irrigation system consists of 3.2 ha (8 acres) of wooded land. The system is composed of 14 separate spray lines in two different fields.

The Kendal/Crosslands Lagoon System serves two retirement villages, namely, Kendal at Longwood, and Crosslands. The system was designed to treat 284 m^3/day (70,000 gpd). Current flow is averaging 189 m^3/day (50,000 gpd). As would be expected, 100 percent of the flow is domestic.

The facility has been in operation for seven years. Adjacent to the spray application site is the Kendal at Longwood retirement community on one side, and wooded land on the other sides. There are no plans for changes to the system in the future.

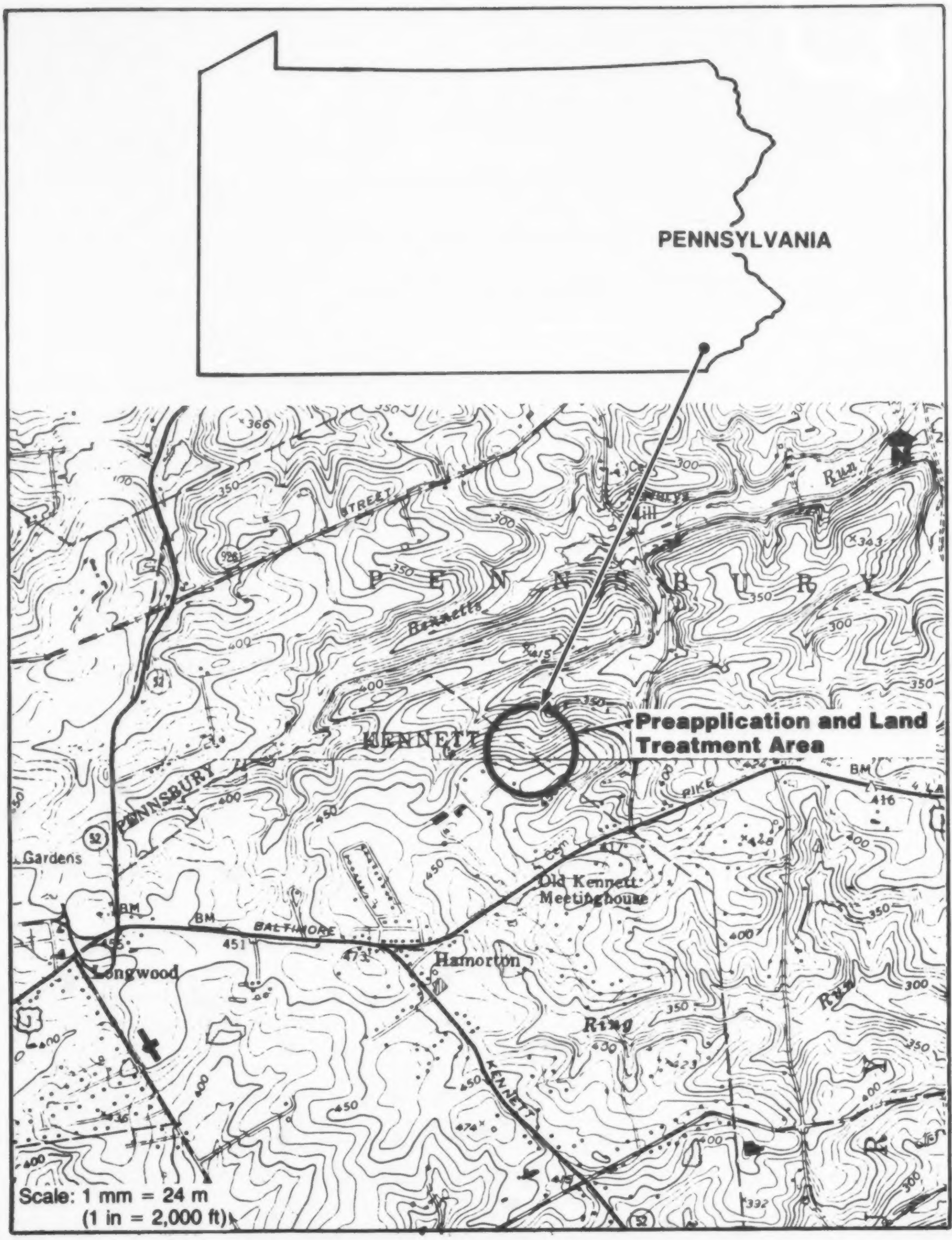

PENNSYLVANIA
Preapplication and Land Treatment Area
PENNSBURY
KENNETT
PENNSBURY
Gardens
Longwood
BALTIMORE
PIKE
Old Kennett Meetinghouse
Hamorton
KENNETT
Ring
Run
N
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-64. Location map of Kendal/Crosslands lagoon system (# 022), Kennett Square, Pennsylvania.

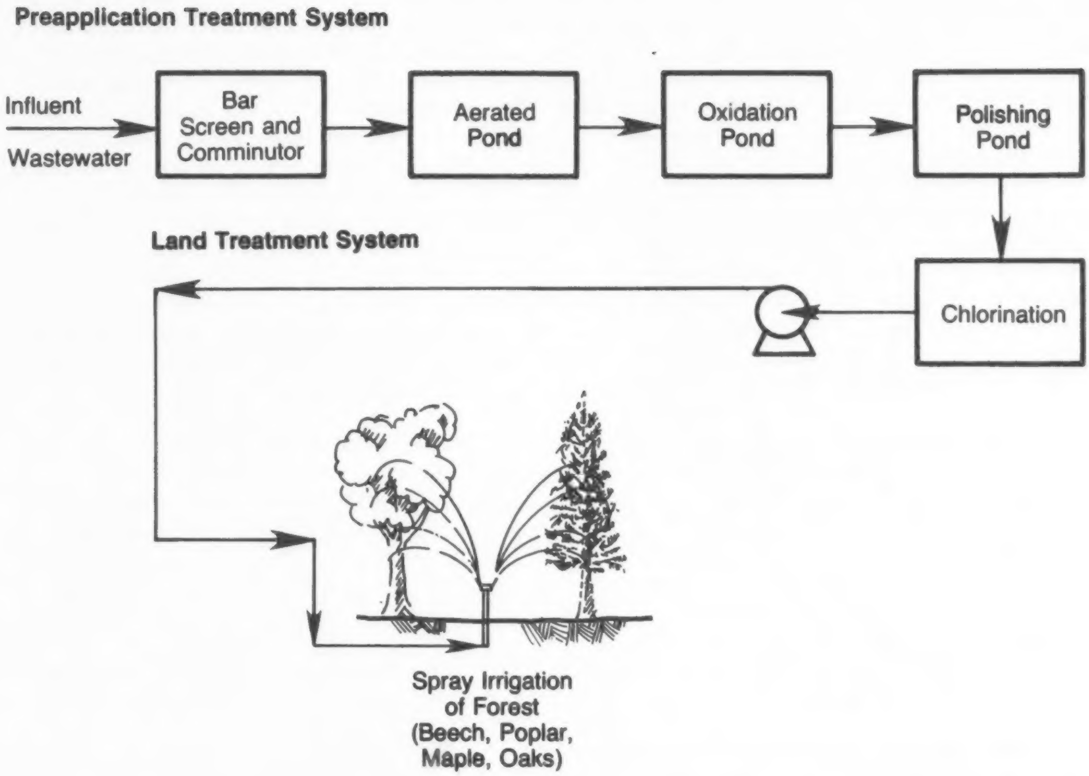

Preapplication Treatment System
Influent
Wastewater
Bar
Screen and
Comminutor
Aerated
Pond
Oxidation
Pond
Polishing
Pond
Land Treatment System
Chlorination
Spray Irrigation
of Forest
(Beech, Poplar,
Maple, Oaks)

Figure A-65. Process flow diagram of Kendal/Crosslands lagoon system (# 022), Kennett Square, Pennsylvania.

PHYSICAL FACILITIES

The preapplication treatment system consists of preliminary treatment followed by biological treatment. Preliminary treatment consists of a hand-cleaned bar screen followed by a comminutor. The wastewater then flows directly into an aerated pond. The aerated pond covers a surface area of 0.128 ha (0.30 acre), is 4.0 m deep (13 ft), and contains 1,491 m^3 (0.394 mil gal). Aeration is provided by a 7.5-kw (10 hp) loading surface aerator. In addition, a ring diffuser is placed at the bottom of the pond to help maintain aerobic conditions. Wastewater next flows by gravity to an oxidation pond. The oxidation pond covers 0.68 ha (1.69 acres), is 2.1 m (7 ft) deep, and has a volume of 11,356 m^3 (3.0 mil gal). From the oxidation pond, the wastewater flows to a polishing pond. This pond covers 0.30 ha (0.75 acre), is 2.4 m (8 ft) deep, and contains 2,336 m^3 (0.617 mil gal). Both the oxidation and polishing ponds are Bentonite clay lined. Wastewater overflows the polishing pond into a wet-well structure. During spray irrigation, sodium hypochlorite solution is injected into the discharge side of the pump for disinfection purposes.

The wastewater is pumped utilizing one of two 7.5-kw (10 hp) centrifugal pumps rated at 0.013 m^3/s (200 gpm). The land treatment system consists of two fields, each covering approximately 1.62 ha (4 acres) for a total area of 3.24 ha (8 acres). The wastewater is distributed utilizing 67 sprinklers located in 14 separate spray lines (Figure A-66). Each sprinkler can cover a 25.3-m (83 ft) diameter circle. The older spray field is designed so that there are multiple drains per each spray line. On the newer spray field, a single drain (located close to other spray field drains) is used to drain the entire line.

The spray irrigation system was constructed in a stand of native trees which consists of beech, maple, poplar, and oak. A total of seven groundwater monitoring wells have been installed in and around the two spray fields. The soils in the area of the spray fields are basically silt and loam. There are no storage facilities, however, storage is possible due to the variable levels in the three ponds.

Based on the current flow rate (excluding evaporation losses), the following application rates exist for the spray application field:

Hydraulic	2.1 m/yr 40.6 mm/wk
Organic	320 kg BOD_5/ha/yr
Solids	428 kg SS/ha/yr

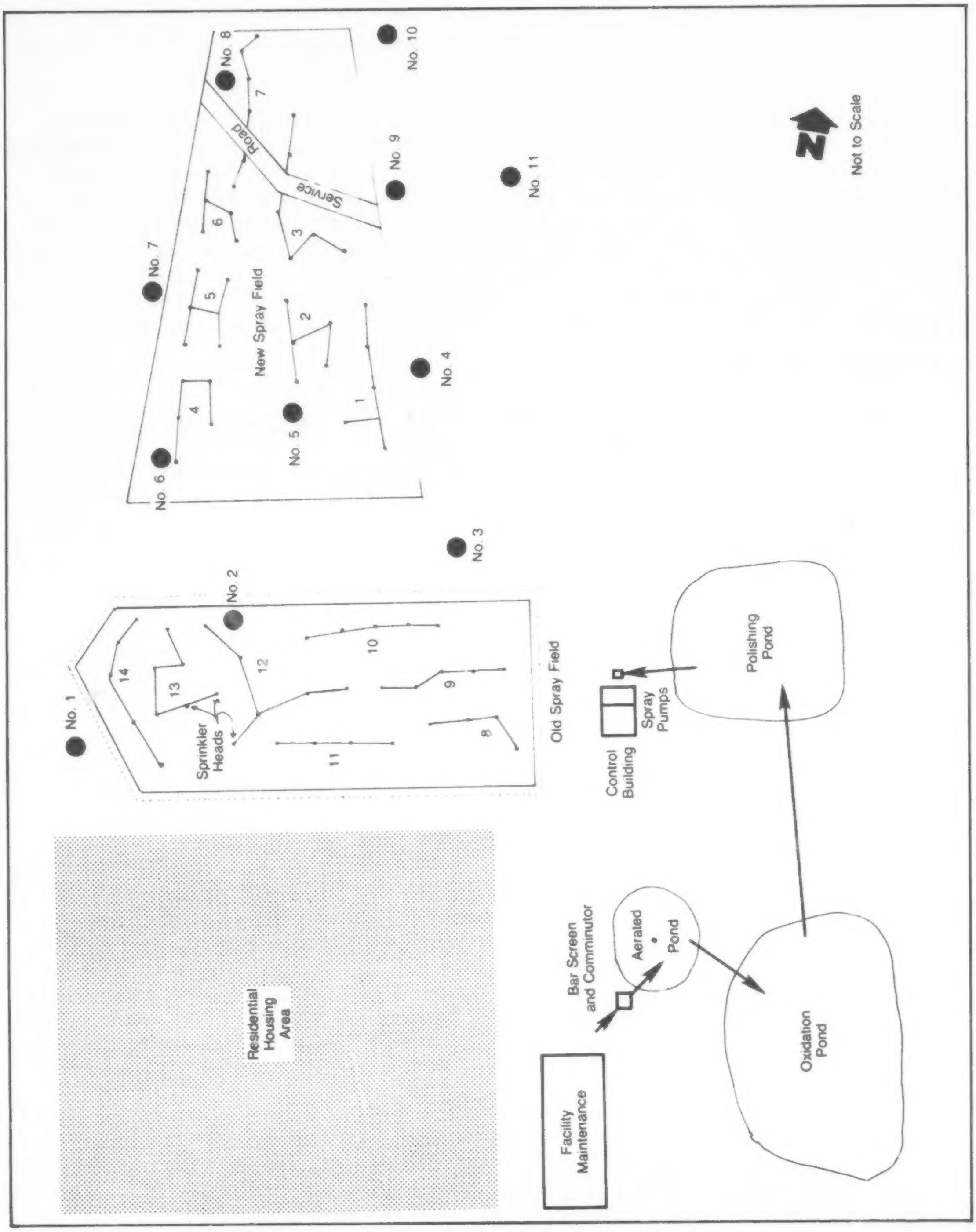

No. 1
No. 2
No. 3
No. 4
No. 5
No. 6
No. 7
No. 8
No. 9
No. 10
No. 11
New Spray Field
Service Road
1
2
3
4
5
6
7
Old Spray Field
Sprinkler Heads
8
9
10
11
12
13
14
Control Building
Spray Pumps
Polishing Pond
Residential Housing Area
Bar Screen and Comminutor
Aerated Pond
Oxidation Pond
Facility Maintenance
N
Not to Scale

Figure A-66. Facility layout of Kendal/Crosslands lagoon system (# 022), Kennett Square, Pennsylvania.

Nutrient	219 kg NH_3-N/ha/yr 149 kg PO_4-P/ha/yr

A minimum buffer zone of approximately 46 to 61 m (150 to 200 ft) is maintained between the spray application site and the nearest residence. This area is grass and tree covered. All stormwater runoff from the retirement community is diverted around the spray irrigation site. Any stormwater generated at the spray site would run off onto adjacent properties. Site access to the older spray fields is controlled by a fence and signs. Access is permitted in the vicinity of the new spray fields, and, in fact, there are some nature trails in the area.

FACILITY OPERATIONS

Under normal operating conditions, sufficient storage capacity is available in the polishing and oxidation ponds in case of inclement weather conditions. The biological treatment system is effective in producing a secondary effluent of the following quality:

BOD_5, mg/L	15
Suspended solids, mg/L	20
pH	8.0
NH_3-N, mg/L	10.5
PO_4-P, mg/L	7
Fecal coliforms, no/100 ml	<3

The current operating strategy for the spray irrigation plots consists of utilizing four to six of the 14 spray plots daily, evenly divided among the two fields. Water typically is sprayed 24 hours per day, five days per week. The plots in use are rotated daily. Spray irrigation continues 12 months of the year. However, water typically is not sprayed on any day on which the temperature is lower than -6.7°C (20°F). During winter operations, the lines are quickly drained after usage to prevent freezing.

In terms of operational problems, the old spray field with its multiple drain points (scattered at various locations) causes the operator a real headache under winter conditions. The new field has only one drain per line and the drains for various lines are located next to each other, making winter operation much easier.

During the plant visit it was noted that there appeared to be a spring which was generated at the spray irrigation site. This discharge appears to be excess spray water which had outcropped from the soil.

One operator spends approximately six hours per day, five days per week in operating and maintaining the wastewater treatment and spray irrigation facility. Of this total, two hours per day is associated with the spray irrigation system.

FACILITY MAINTENANCE

There is a minimum amount of mechanical equipment associated with the preapplication treatment system. Overall maintenance at the plant appeared adequate, however. There is one maintenance problem associated with the valves used to turn various spray plots on and off. The box for these underground valves is constructed of PVC pipe, and due to frost heaving, the pipe is sometimes pushed up. Dirt then falls in from the bottom, and a backhoe has to excavate, and remedy the situation. An additional maintenance problem is due to the nibs from maple trees which occasionally fall into the polishing pond and are sucked up through the spray irrigation system, and jam in the spray nozzles. The problem is easily fixed by turning the nozzle's rotating aperture around to the large size, and simply blowing the piece out.

OPERATION AND MAINTENANCE COSTS

A total of $15,000 was spent during calendar year 1978 for operation and maintenance of the Kendal/Crosslands Lagoon System. Of this total, 37 percent or $4,070 was associated with land application as follows:

Personnel	$1,070
Fuel and electricity	2,200
Maintenance and repair	800
Total	$4,070

DESIGN DEFICIENCIES

There are two design deficiencies, both of which have been previously alluded to. The first involves the fact that the maple tree nibs get into the system and plug the spray nozzles. The second problem involves the valve boxes which are subject to frost heaving requiring subsequent excavation to allow operation of the valve.

LANDIS SEWAGE AUTHORITY (# 023)

VINELAND, NEW JERSEY

RAPID INFILTRATION SYSTEM

GENERAL

The City of Vineland is located in southern New Jersey, approximately 56 km (35 mi) due south of Philadelphia, Pennsylvania (Figure A-67). The City of Vineland is served by two wastewater treatment facilities. The older and smaller facility is owned by the City of Vineland Water and Sewer Utility Authority, whereas the newer and larger facility is owned by the Landis Sewage Authority. The two plants are located almost adjacent to each other. The larger Landis Sewage Authority plant was visited on June 5, 1980.

Vineland, New Jersey has a temperate climate. The yearly average temperature is 12.2°C (54°F), whereas the yearly average precipitation is 1.0 m (40.1 in). The estimated yearly Class A pan evaporation is 1.1 m (45 in).

The Landis Sewage Authority wastewater treatment facility provides primary treatment to 0.18 m^3/s (4.0 mgd). The flow consists of 0.11 m^3/s (2.4 mgd) of domestic waste, and 0.07 m^3/s (1.6 mgd) of industrial wastewater. The industrial flow is generated by food processing, canning, slaughterhouse, poultry, and glass industries, resulting in influent wastewater which is higher in BOD_5 than typical domestic wastewater. The system was originally designed to handle 0.31 m^3/s (7 mgd). Following primary treatment, wastewater next flows to a rapid infiltration land treatment system (Figure A-68).

Both the treatment plant and the rapid infiltration system have been in operation for approximately 30 years. The zoning in and around the treatment facilities is industrial recycling, as the plant abuts both a county sanitary landfill and the City of Vineland Wastewater Treatment facilities.

Future plans call for expansion and upgrading of the facility. During expansion, plant capacity will be increased to

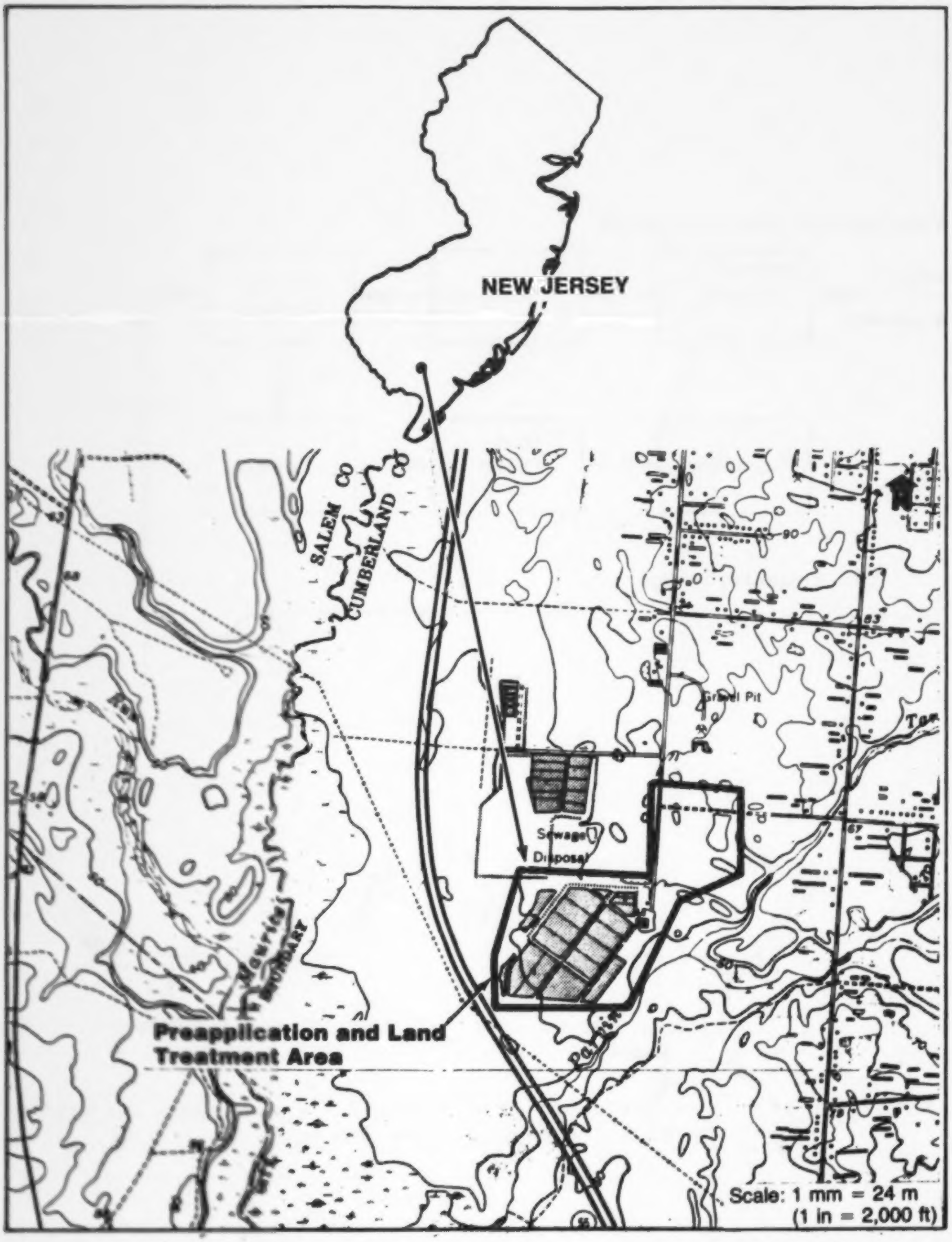

NEW JERSEY
SALEM CO
CUMBERLAND CO
Gravel Pit
Sewage Disposal
Preapplication and Land Treatment Area
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-67. Location map of Landis Sewage Authority (# 023), Vineland, New Jersey.

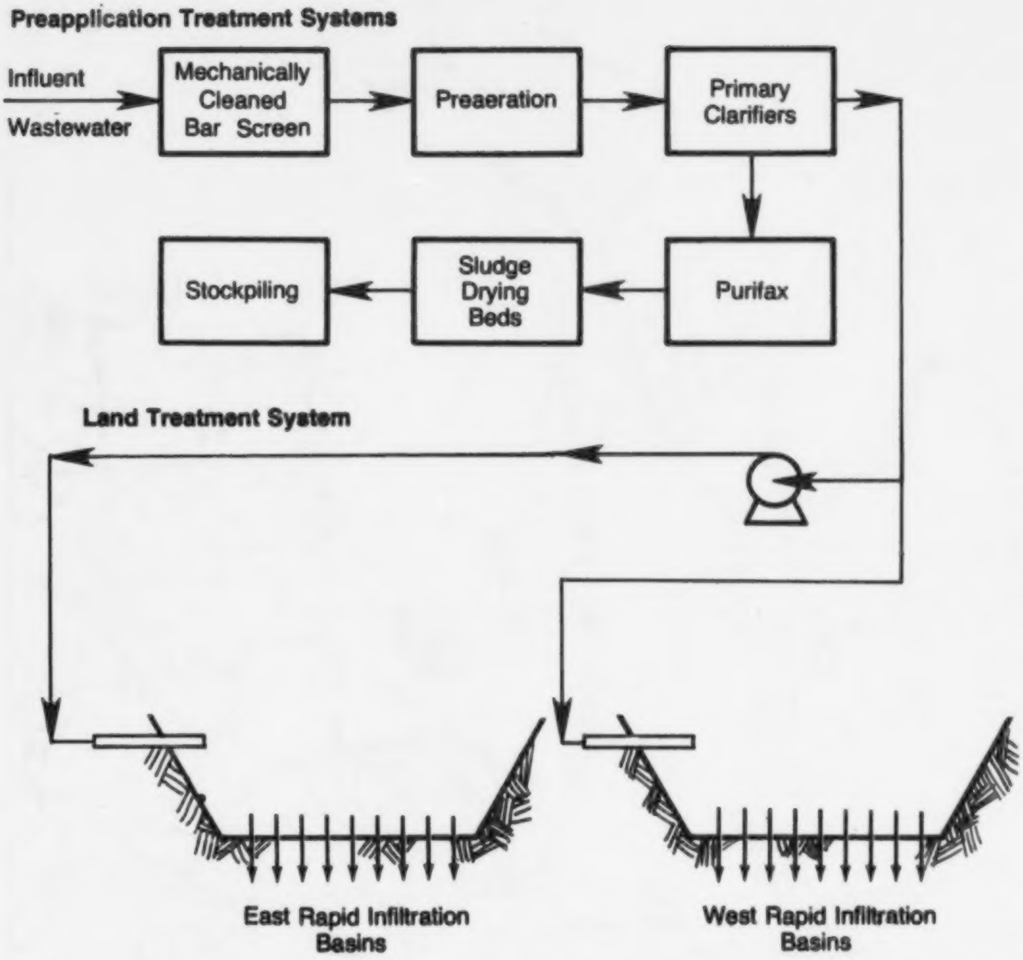

Preapplication Treatment Systems
Influent
Wastewater
Mechanically Cleaned Bar Screen
Preaeration
Primary Clarifiers
Purifax
Sludge Drying Beds
Stockpiling
Land Treatment System
East Rapid Infiltration Basins
West Rapid Infiltration Basins

Figure A-68. Process flow diagram of Landis Sewage Authority (# 023), Vineland, New Jersey.

0.35 m^3/s (8 mgd). Upgrading of the facility will include installation of secondary treatment facilities, and abandonment of the rapid infiltration system and replacement by a slow-rate system. These changes have been mandated by the New Jersey Department of Environmental Protection due to groundwater contamination, primarily by nitrogen. Consideration is being given to growing various crops using the slow-rate system, including typical row crops, but also hybrid poplars for pulp production, and biomass production for conversion to ethanol.

PHYSICAL FACILITIES

Wastewater at the Landis Sewage Authority is screened, pumped into a preaeration tank, settled in six primary clarifiers, and then flows by gravity to a diversion structure. The diversion structure is used to either divert wastewater directly to the west infiltration beds, or pump it to the east infiltration beds. The primary sludge is treated by chlorination (Purifax), and put on sand drying beds. Sludge is currently stock-piled on-site.

The rapid infiltration beds are located both to the southwest (west beds) and the northeast (east beds) of the treatment facility (Figure A-69). The west beds were constructed in 1948, and consist of 12 beds comprising a total area of approximately 14.2 ha (35 acres). The east beds were constructed in 1974, and consist of six beds with a total area of 12.1 ha (30 acres). Therefore, the total acreage of the infiltration beds is approximately 26.3 ha (65 acres). The soils in the vicinity of the plant are rapidly permeable, deep, well-drained, sandy soils.

The infiltration beds range in size from approximately 0.81 (2 acres) (west beds) to 2.4 ha (6 acres) (east beds) in size, and are essentially flat. Two types of wastewater inlet structures are used. In the older beds, wastewater is distributed by in-ground standpipes. In some of the beds, these standpipes are located at the base of the basin berm and the water "bubbles" up, and spreads throughout the bed, whereas in other beds, the water bubbles out the standpipes at the top of the basin embankment, and runs down the sidewall which is covered with crushed rock to facilitate distribution and minimize erosion. In the new beds, the wastewater distribution consists of a wheel-operated sluice gate built into a concrete headwall and splash plate structure. All permanent piping at the facility is in-ground. There is no allowance for wastewater storage (aside from the beds themselves). There are three on-site monitoring wells. However, only the groundwater elevation is monitored.

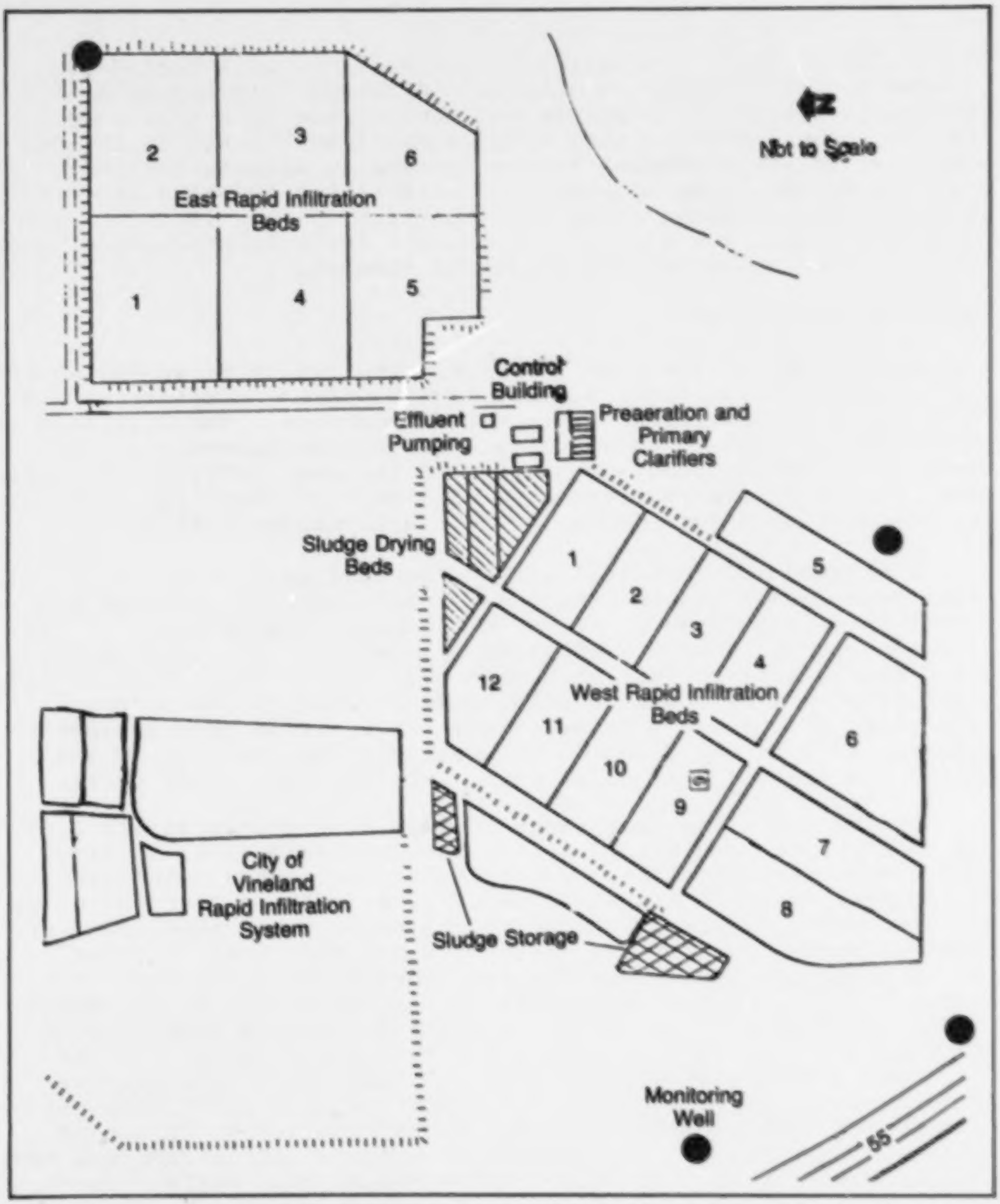

Not to Scale
East Rapid Infiltration Beds
1
2
3
4
5
6
Control Building
Effluent Pumping
Preaeration and Primary Clarifiers
Sludge Drying Beds
West Rapid Infiltration Beds
1
2
3
4
5
6
7
8
9
10
11
12
City of Vineland Rapid Infiltration System
Sludge Storage
Monitoring Well
55

Figure A-69. Facility layout of Landis Sewage Authority (# 023), Vineland, New Jersey.

Due to their later installation and the physical constraints of the plant site, all wastewater must be pumped up to the east beds. Two centrifugal trash pumps are utilized for this purpose, each capable of pumping approximately 0.066 m^3/s (1,070 gpm). One pump is typically run and rotated daily with the other pump.

Due to a lack of analytical data, only the average hydraulic loading rate can be calculated. Based on 0.18 m^3/s (4.0 mgd) and 26.3 ha (65 acres) of infiltration beds, 21.0 m (68.9 ft) of water, is applied per year, corresponding to a yearly weekly average of 0.40 m/wk (1.3 ft/wk).

FACILITY OPERATIONS

Based on data presented by Koerner and Haws (1979), the Landis Sewage Authority plant preapplication effluent on the average contains 149 and 41 mg/L BOD_5 and suspended solids, respectively.

The preapplication effluent is applied to the infiltration beds 24 hours per day, 365 days per year. Typically, one west infiltration bed and one east infiltration bed are concurrently in use. Therefore, the level-controlled effluent pumps cycle continuously. The typical operation cycle for an infiltration bed is to leave the bed in service until either 24 hours has elapsed, or there is 0.15 m (6 in) of standing water.

Prior to 1974 and the installation of the east beds, wastewater was applied to the beds continuously as opposed to the current intermittent operation. As will be discussed in the next section, the current method of intermittent bed operation and maintenance has minimized operational problems. In terms of operating strategy, beds are merely rotated on a more or less rigorous schedule. Following the filling of a bed, it drains in one to two days and is ready to be worked.

Currently, there are no operational problems associated with the infiltration beds. However, previous problems were associated with bed plugging. This caused a variety of problems, including a lack of sufficient capacity and odors. Although current maintenance practices have minimized this problem, at the time of the site visit a few of the older west beds were clogged. These beds have had problems for years, and the Authority is in the process of revitalizing these beds even though they are still receiving flow. Several beds have recently been revitalized and are currently operating again.

A seven-man staff operates and maintains the treatment facility, the land application system, and the 15 pumping stations in the collection system. Three men (laborers) are basically involved full-time with operating, but primarily maintaining the infiltration beds.

FACILITY MAINTENANCE

The preapplication treatment facility maintenance appeared somewhat poor, but adequate. Considering the plant is 30 years old and facility expansion and upgrading is planned, maintenance was adequate. Maintenance for the land treatment portion of the facility, especially the infiltration beds, was excellent. The remainder of the equipment (i.e., pumps, valves, piping) was maintained adequately. The reason for the beds being so well maintained is that, historically, poor maintenance of the beds has severely affected plant operation due to bed clogging.

Currently, following every cycle of wastewater application to the beds the beds are reworked after they have dried completely. A tractor with a chisel plow first enters the bed and breaks up the top 0.30 m (12 in). When approximately 50 percent of the bed is chisel plowed, a second tractor with a springtooth harrow enters, and causes additional mixing, but more importantly levels the bed. Finally, a third tractor towing a fence drag (a weighted-down piece of chain link fence) goes through the bed and smooths and levels the surface so that the water cannot pond. After sitting a day, the bed is ready to be refilled. The entire bed revitalization process takes approximately two to three hours. Approximately once per year a front-end loader on tracks is used to turn over approximately the top 0.9 m (3 ft) of the bed. This breaks up any deep accumulation of "impermeables." For the older west beds that were experiencing problems, this deep cleaning, followed by the normal cleaning process, has been effective in revitalizing the beds.

Although the current bed maintenance practice may be excessive, the previous problems have caused the authority personnel to be leery, and to try to stay ahead of the problem. Another reason for such frequent working of the beds is due to a sticky substance believed associated with a clam canning industrial wastewater which is received by the plant.

OPERATION AND MAINTENANCE COSTS

A total of $332,000 was spent by the Landis Sewage Authority on operation and maintenance of the facility. Of this, 30% or $100,100 was spent on land application as follows:

Personnel	$ 52,600
Materials and supplies	2,000
Fuel and electricity	12,500
Insurance	7,500
Engineering services	2,000
Communication	5,500
Maintenance and repairs	15,000
Equipment purchase	3,000
Total	$100,100

DESIGN DEFICIENCIES

According to the Landis Sewage Authority personnel, there were no design deficiencies associated with the rapid infiltration system. Based on the simplicity of the system and the site visit, this was confirmed by the site survey. The only potential design deficiency involved the need to pump to the newer east beds. Possibly more judicious plant location in 1948 could have eliminated the need for pumping as the influent wastewater is pumped to the preaeration tanks.

CAMPBELL SOUP (TEXAS), INC. (# 024)

PARIS, TEXAS

OVERLAND FLOW SYSTEM

GENERAL

The City of Paris, Texas is located in northeast Texas, close to the Oklahoma border and approximately 161 km (100 mi) northeast of Dallas (Figure A-70). The overland flow treatment system is owned and operated by Campbell Soup (Texas), Inc. The facility was visited on June 9, 1980.

The climate in the Paris, Texas area is categorized by mild, seasonal weather with an average annual temperature of 17.3°C (63.1°F). The average annual rainfall is 1.15 m (45.17 in), whereas the mean annual Class A pan evaporation is 1.91 m (75 in).

The preapplication treatment system at Campbell Soup was designed to be compatible with the overland flow system. Preapplication treatment consists of oil and grease separation, and screening prior to application to the overland flow site (Figure A-71). The entire overland flow site currently consists of approximately 364 ha (900 acres). The plant has been upgraded various times, and is currently designed to handle 0.228 m^3/s (5.2 mgd). Flow at the facility has been averaging 0.180 m^3/s (4.1 mgd) on a yearly average but 0.223 m^3/s (5.1 mgd) for the five-day work week.

The facility has been in operation for 16 years treating the industrial wastewater from Campbell Soup. It treats no sanitary flow as sanitary wastewater enters the City of Paris municipal facilities. The land use adjacent to the land treatment site is commercial, industrial, and agricultural.

PHYSICAL FACILITIES

Of the various wastewater streams generated at the Campbell Soup Plant in Paris, only the grease and vegetable wastewater reaches the treatment facility. Inside the factory, two collection systems separately collect the grease wastewater and the

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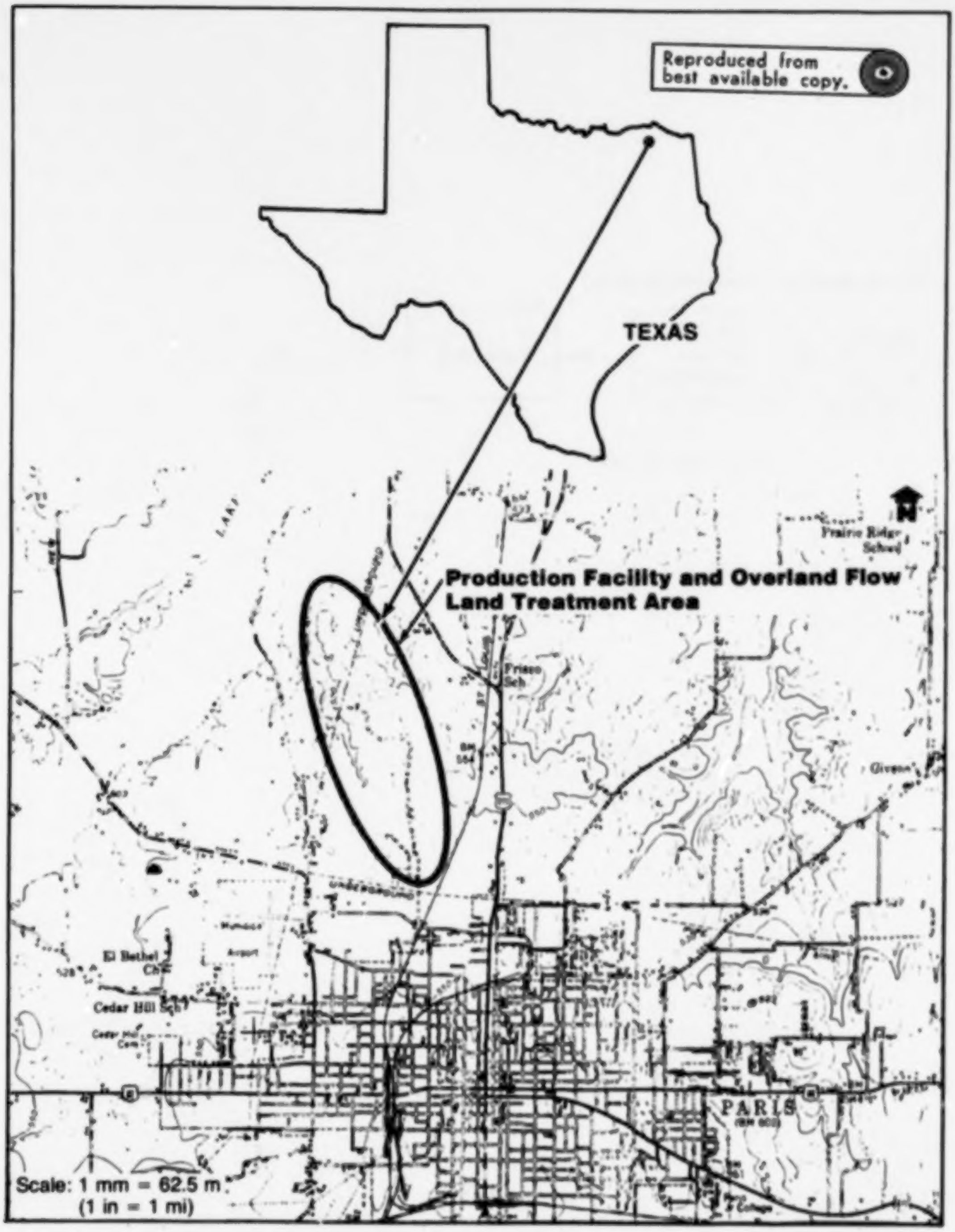
TEXAS
Production Facility and Overland Flow
Land Treatment Area
Prairie Ridge School
Frisco Sch
Givens
El Bethel Ch
Cedar Hill Sch
Airport
PARIS
N
Scale: 1 mm = 62.5 m
(1 in = 1 mi)

Figure A-70. Location map of Campbell Soup (Texas), Inc. (# 024), Paris, Texas.

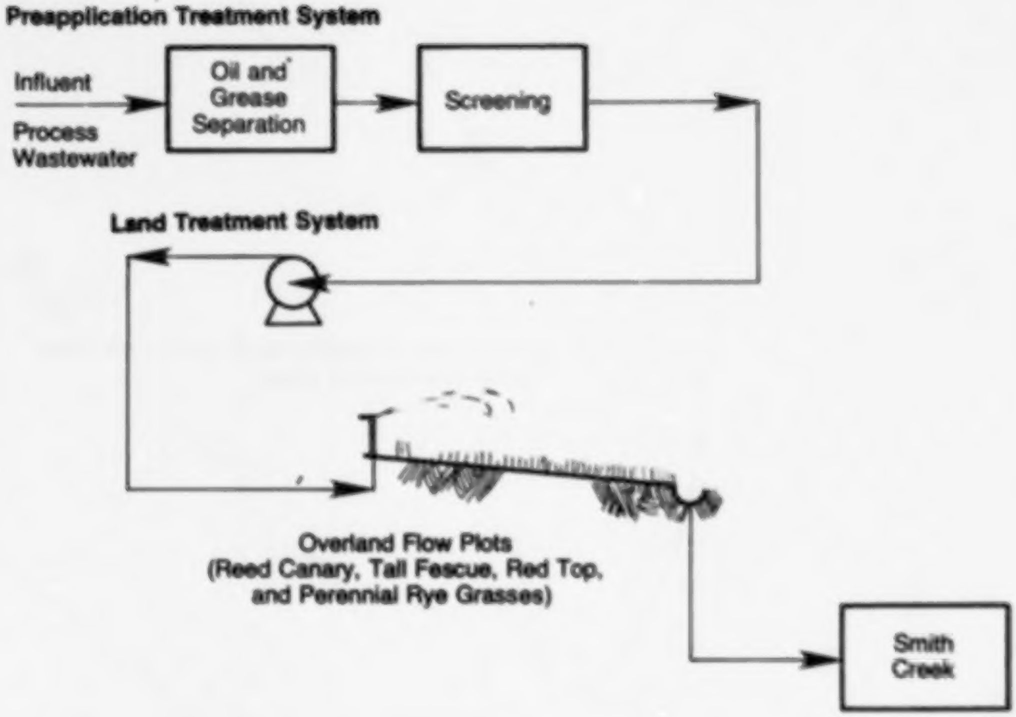
Preapplication Treatment System
Influent
Process Wastewater
Oil and Grease Separation
Screening
Land Treatment System
Overland Flow Plots
(Reed Canary, Tall Fescue, Red Top, and Perennial Rye Grasses)
Smith Creek

Figure A-71. Process flow diagram of Campbell Soup (Texas), Inc. (# 024), Paris, Texas.

vegetable wastewater, which then flow by gravity to the preapplication treatment building. The grease wastewater travels through an oil/water separator where it joins the vegetable wastewater stream. The combined wastewater flows through rotating drum screens (No. 10 mesh) where the vegetable solids are removed. The grease is rendered in kettles and sold to a local rendering company, while the vegetable solids are hauled away and processed for animal feed.

After screening, the wastewater flows by gravity to a 379 m^3 (100,000 gal) wet well/surge tank. The wastewater is pumped from the wet well utilizing six pumps: two newer 74.6-kw (100 hp) pumps rated at 0.095 m^3/s (1,500 gpm) and four older 56.0 kw (75 hp) pumps rated at 0.066 m^3/s (1,050 gpm). All six pumps are centrifugal nonclog and are level controlled.

The level controls of the pump system are tied in to an automatic controller which controls automatic valves at the lateral sprinkler lines. The timer enables switching the fields after a fixed period of watering time. The wastewater is pumped at 483 kPa (70 psi) to the 235 ha (581 acres) of overland flow plots (Figure A-72). Each of the overland flow plots or terraces is approximately 76.2 m (250 ft) wide with the length variable, depending on the parcel of land's physical constraints. Sprinklers are located approximately one-quarter of the way down the terrace. This allows the spray to cover approximately the top half of the overland flow plot, and flow over the bottom half of the plot. The terraces are sloped at 2 to 8%, with 6% being the most favorable slope. Wastewater is distributed through a series of underground force mains constructed out of concrete pipe. Lateral lines consist of 0.10-m (4 in) aluminum irrigation pipe which is laid on top of the ground in the oldest fields. In the sections which were installed later, laterals have been placed underground. Automatic valves are placed between the force main and the laterals, and the valves are air operated. A network of air tubes lead back to the controller which actuates the valves.

There is a total of 1,000 spray nozzles on the overland flow site. The nozzles are approximately 24.4 m (80 ft) apart, and each is capable of spraying 120 m^3/day (22 gpm) with a nozzle size of 7.9 mm (5/16 in).

The soil which underlies the spray irrigation overland flow site is mostly gray clay loam underlain by a red clay subsoil. A mixture of cool season grasses is planted on the plots. This includes reed canary, tall fescue, red top, and perennial rye grasses. There are no groundwater monitoring wells in the vicinity of the Campbell Soup overland flow site.

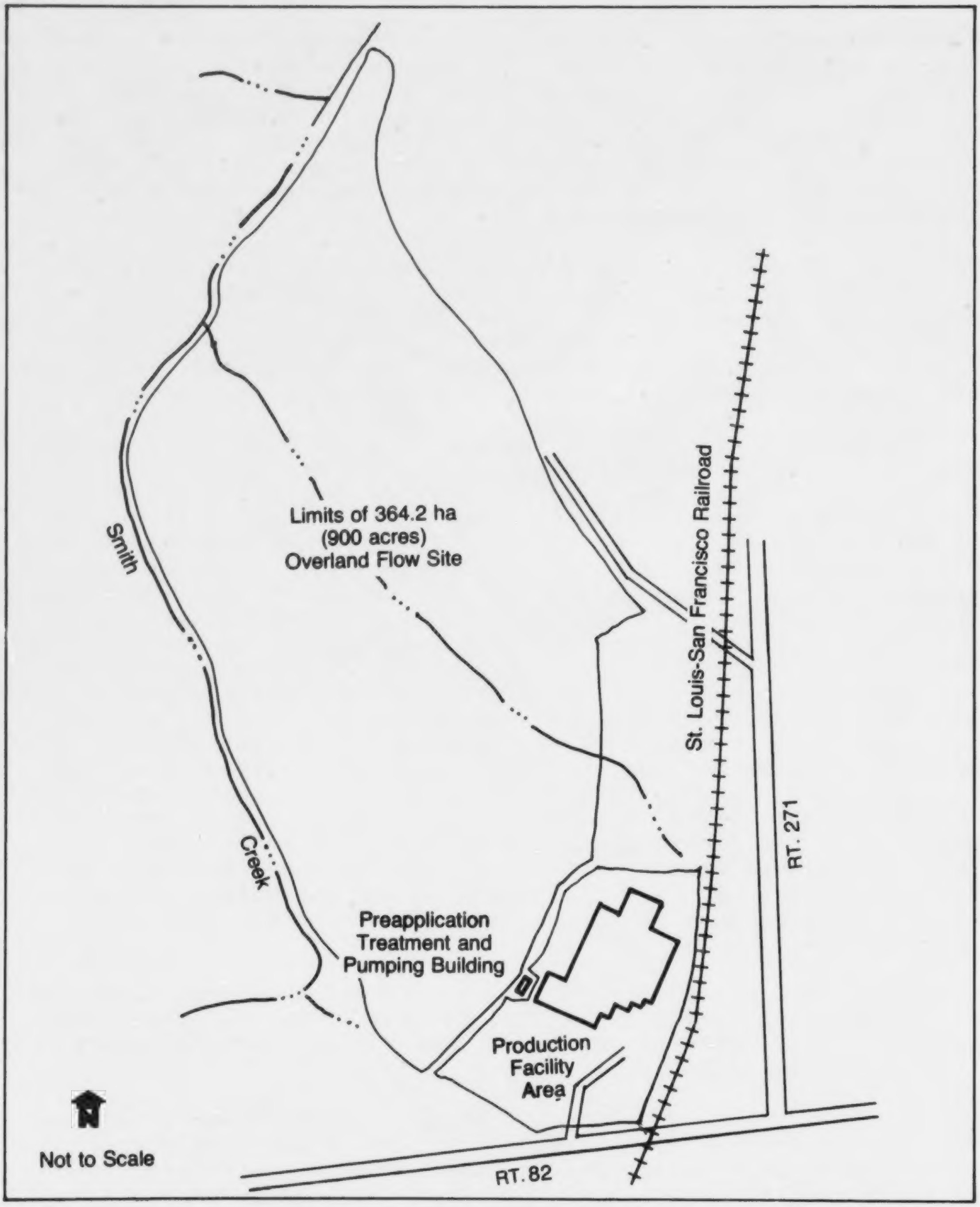
Limits of 364.2 ha
(900 acres)
Overland Flow Site
Smith
Creek
St. Louis-San Francisco Railroad
RT. 271
Preapplication
Treatment and
Pumping Building
Production
Facility
Area
RT. 82
N
Not to Scale

Figure A-72. Facility layout of Campbell Soup (Texas), Inc. (# 024), Paris, Texas.

Based on the influent quality, the following loading rates have been calculated for the facility:

Hydraulic	2.1 m/yr 40.6 mm/wk
Organic	12,790 kg BOD_5/ha/yr
Solids	5,595 kg SS/ha/yr
Nutrient	370 kg total N/ha/yr 160 kg T-P/ha/yr

It should be noted that the hydraulic loading rate was 15.2 mm/day (0.6 in/day) for over 10 years prior to the expansion of the overland flow site, and that the removal efficiencies were comparable to those of today. Expansion of the site was made due to an expected increase in the plant size and processing capacity which has not yet occurred. The overland flow site was not expanded due to overloading or poor treatment efficiency. It is felt by Campbell Soup personnel that the current site is capable of treating loads up to 15.2 mm/day while maintaining the same effluent quality and removal efficiency it does today.

There are no storage facilities at the Paris, Texas site. A minimum buffer zone of 30.5 m (100 ft) exists between the nearest spray field and adjacent property. The entire site is fenced to control public access. In terms of runoff, all surface runoff which is generated within the treatment plant fields is discharged to Smith Creek with the process water.

FACILITY OPERATIONS

The preapplication treatment of oil and grease removal and screening appears to be effective as spray nozzle plugging and oil and grease accumulation do not appear to be problems with the overland flow system. The operating strategy of the overland flow system is fairly simple and consists of a rotation schedule. During the winter, a field is normally sprayed for six hours per day with an 18-hour rest period. In the summer, the field is sprayed for eight hours with a 16-hour rest period. The entire operation facility is controlled by the pneumatic valve timer controller.

Since the grasses in the spray fields are perennials, there is no requirement for yearly turf replanting. Currently, about 14.2 ha (35 acres) of corn have been planted as a strictly experimental crop, and there are no data available yet. All of the grass harvesting is handled by a private contractor, and, depending on weather conditions, approximately 10 days are needed between the time a field is taken out of service and is ready for harvesting. The grass that is harvested is currently used as cattle feed. The grass is no longer dried in a hay drier and made into pelletized animal feed, due to the high costs of drying. It should be noted that within the sprinkler pattern nearly all of the grass is reed canary as this grass fares very well in the wet system. In addition, flags have been placed to mark the location of the spray system so that people harvesting the crop do not run over the sprinkler header pipes. Campbell Soup attempts to harvest the grass twice a year. However, conditions are not always favorable.

During storm events, wastewater spraying is continued, however, a large volume of stormwater is generated on-site and the entire runoff for the site is discharged to Smith Creek. The discharge permit states that a maximum of 20 mg/L BOD_5 must be maintained in the effluent even during storm events, whereas the suspended solids limitation is waived.

Based on operating data from August 1978 to July 1979, the following effluent quality was produced by the overland flow treatment system:

BOD_5, mg/L	5.9
Suspended solids, mg/L	31
Oil and grease, mg/L	5.1
Sulfates, mg/L	49.3
Color, Pt/Co units	41.7
pH	7.2

FACILITY MAINTENANCE

The overall preapplication treatment facility maintenance appeared good. There is minimal maintenance associated with the overland flow system. One maintenance problem that was noted involved some ponding of water in the fields due to settlement of the soil. These ponds were causing some odor problems.

A total staff of seven people is utilized for operation and maintenance, including four shift operators, three laborers, and one maintenance man. In addition, the chief operator spends approximately 60% of his time at the facility.

OPERATION AND MAINTENANCE COSTS

A total of $181,140 was spent by Campbell Soup in operating the overland flow treatment system for fiscal year 1978-1979. The breakdown is as follows:

Personnel	$116,000
Materials and supplies	35,900
Maintenance and repairs	15,340
Laboratory testing	6,400
Vehicles	7,500
Total	$181,140

This budget expense does not include the time spent by the chief operator, the plant manager, or the manager of plant services (superintendent). In addition, electricity costs could not be separated from plant electricity costs, and are not included. The operation and maintenance expense was somewhat offset by $14,200 received for the grease and hay which were sold.

DESIGN DEFICIENCIES

Based on what has been learned through the years, the slope should be built at 6%. Currently, some of the fields are greater than and some less than 6%, and it is felt that 6% is the optimum slope.

A second design deficiency noted was that PVC pipe should have been used on any pipe less than 0.15-m (6 in) diameter as the concrete or cast iron pipe which was used has been breaking due to soil movement caused by wetting and drying. The third design deficiency noted was that a comprehensive plan for earth moving and grading was not prepared prior to facility construction. For example, the first plot of land at Paris, Texas which was graded, contained approximately 121.4 ha (300 acres). Had the site been properly graded, an additional 30.4 ha (75 acres) of overland flow plot would have been available.

CITY OF COLEMAN WASTEWATER TREATMENT PLANT (# 025)

COLEMAN, TEXAS

SLOW-RATE SYSTEM

GENERAL

The City of Coleman, Texas is located in central Texas approximately 73 km (45 mi) south of Abilene (Figure A-73). The City of Coleman Wastewater Treatment Plant is both owned and operated by the City. The land application system is owned by the City, however, it is operated jointly by the City and a private farmer. The facility was visited on June 10, 1980.

The climate in the vicinity of the City of Coleman would be categorized as mild. The yearly average temperature is 18.6°C (65.4°F). Yearly precipitation averages 0.68 m (26.82 in), and mean annual Class A pan evaporation averages 2.4 m (95 in).

The preapplication treatment for the City of Coleman consists of preliminary treatment followed by secondary biological treatment in an oxidation ditch (Figure A-74). The secondary effluent is pumped to a land treatment system consisting of border strip irrigation of coastal Bermuda grass. In addition, a surface discharge of wastewater is used occasionally. Effluent wastewater is chlorinated when the surface discharge is in use.

The City of Coleman Wastewater Treatment Plant was designed to handle 0.035 m^3/s (0.8 mgd). The facility currently receives approximately 0.018 m^3/s (0.4 mgd), and is therefore operating at 50% of design capacity. Of the flow received at the facility, 100% is of domestic origin. The current biological treatment system has been in operation for six years. Previous to this, oxidation ponds were utilized, and these, along with the land treatment system, have been in use for approximately 50 years. The Coleman Wastewater Treatment Plant and land treatment facilities are located in a basically agricultural area on the east part of town. There are no plans for future modifications or changes to the existing facilities.

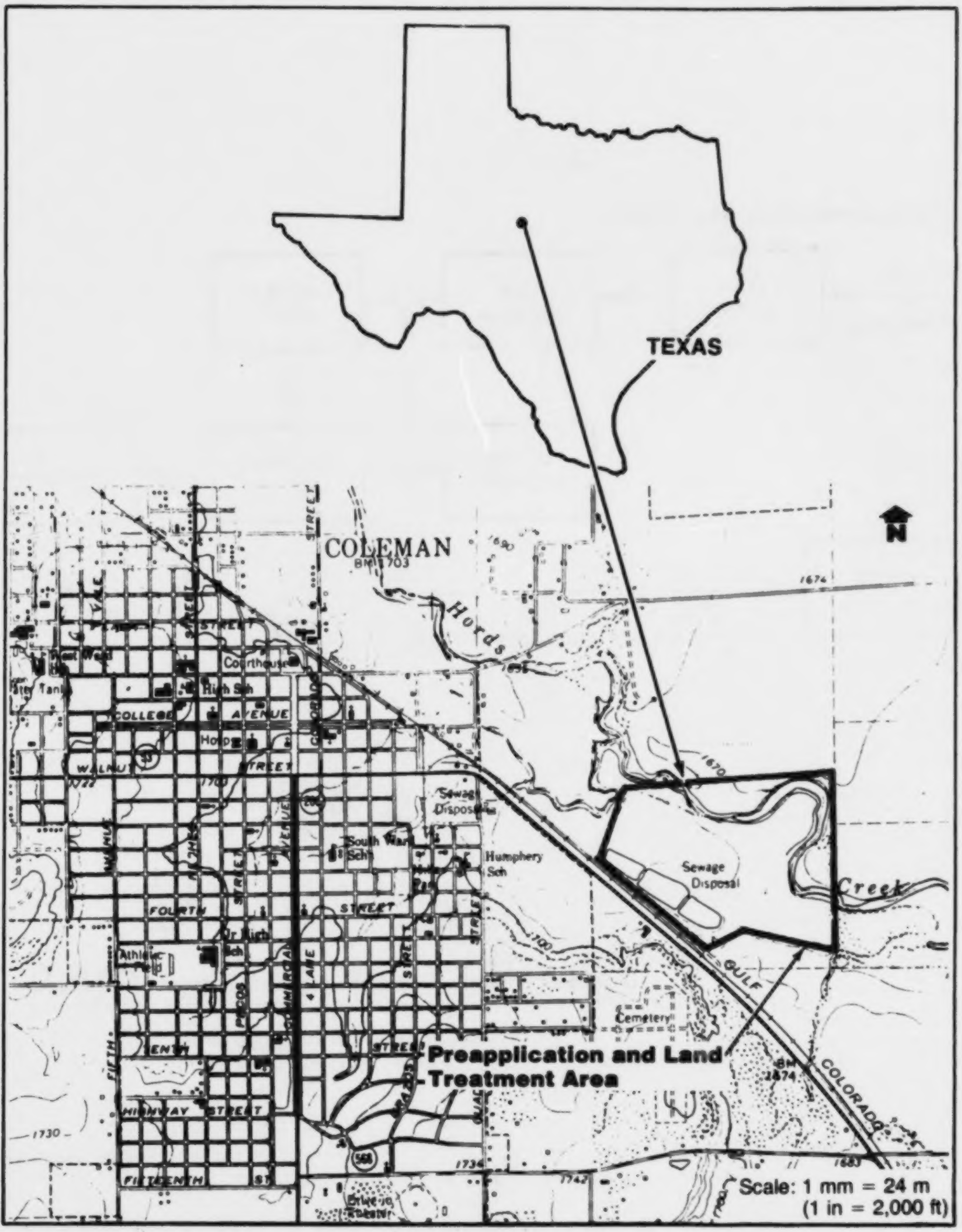
TEXAS
N
COLEMAN
Hords Creek
Courthouse
High Sch
College Avenue
Walnut Street
Sewage Disposal
South Ward Sch
Humphery Sch
Sewage Disposal
Fourth Street
Jr High Sch
Athletic Field
Cemetery
Preapplication and Land Treatment Area
Gulf
Colorado
Highway Street
Fifteenth St
Drive-in Theater
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-73. Location map of City of Coleman wastewater treatment plant (# 025), Coleman, Texas.

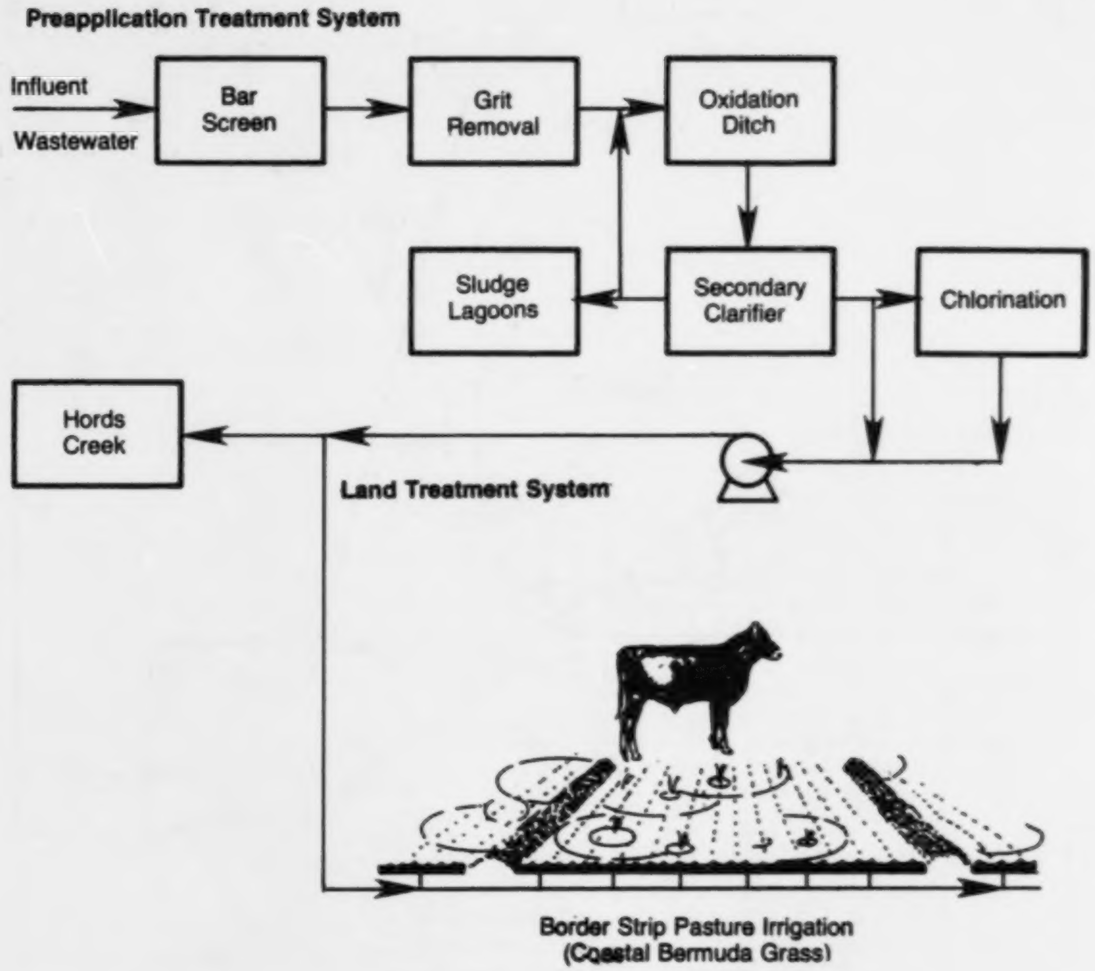
Preapplication Treatment System
Influent
Wastewater
Bar Screen
Grit Removal
Oxidation Ditch
Sludge Lagoons
Secondary Clarifier
Chlorination
Hords Creek
Land Treatment System
Border Strip Pasture Irrigation
(Coastal Bermuda Grass)

Figure A-74. Process flow diagram of City of Coleman wastewater treatment plant (# 025), Coleman, Texas.

PHYSICAL FACILITIES

Wastewater generated in the City of Coleman flows by gravity to an on-site pump station at the treatment plant. The wastewater is then pumped to the headworks of the facility. The headworks consist of two manually-cleaned bar screens and two manually-cleaned grit chambers, followed by a Parshall flume. The grit chamber and bar screens are in parallel operation. Screened and degritted wastewater next flows to an oxidation ditch. The hydraulic detention time in the oxidation ditch is approximately two days. Mixed liquor from the oxidation ditch overflows into a circular secondary clarifier.

Sludge from the secondary clarifier is either returned to the oxidation ditch or wasted to an adjacent lagoon. There are three adjacent lagoons which were built in conjunction with the former treatment facilities. The sludge is stockpiled in the lagoon. The effluent from the clarifier overflows directly into a chlorine contact tank which has common wall construction with the clarifier. Chlorine is injected just prior to the wastewater dropping into the contact tank. Gaseous chlorine from the eductor system is added from 68-kg (150 lb) chlorine cylinders. The wastewater is next pumped to a flow diversion chamber located in the corner of the land treatment facility utilizing one of two centrifugal vertical shaft pumps. The pumps are level controlled and are 7.6-kw (10 hp) pumps rated at 0.035 m^3/s (550 gpm).

At this point flow can either be sent to the receiving stream (Hords Creek) or to the fields for irrigation purposes. The slow-rate land treatment system utilizes 23.1 ha (57 acres) of border strip irrigation fields (Figure A-75). All wastewater is distributed in earthen-lined and partially grassed channels to the various fields. The fields are approximately 0.40 to 0.61 ha (1 to 1.5 acre) plots that are located adjacent to a distribution channel. Wastewater is diverted to any of the channels utilizing gates and terracotta pipes through the berm walls. Berms are approximately 0.30 m (1 ft) high. The major crop grown in the fields is coastal Bermuda grass, however, some weeds are also present. The area is used as pasture for cattle.

The slow rate irrigation system is loaded at the following application rates:

Hydraulic	1.68 m/yr 32.3 mm/wk
Organic	67.2 kg BOD_5/ha/yr
Solids	16.8 kg SS/ha/yr

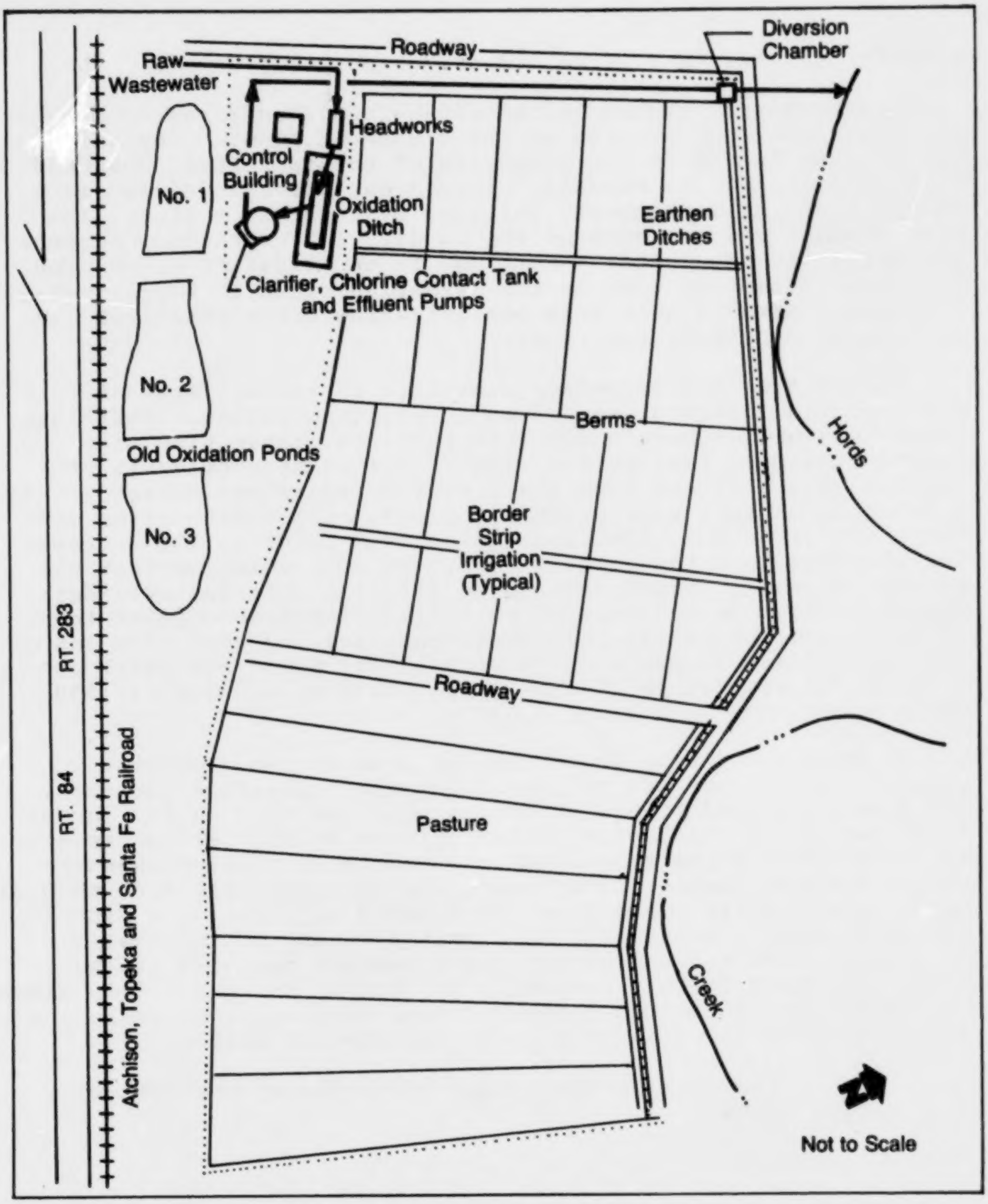
Diversion Chamber
Roadway
Raw Wastewater
Headworks
Control Building
No. 1
Oxidation Ditch
Earthen Ditches
Clarifier, Chlorine Contact Tank and Effluent Pumps
No. 2
Berms
Hords
Old Oxidation Ponds
No. 3
Border Strip Irrigation (Typical)
RT. 283
Roadway
RT. 84
Atchison, Topeka and Santa Fe Railroad
Pasture
Creek
N
Not to Scale

Figure A-75. Facility layout of City of Coleman wastewater treatment plant (# 025), Coleman, Texas.

Although there are three old oxidation ponds on-site, they are not used for treated wastewater storage. In addition, there are no groundwater monitoring wells on-site. Site access is controlled by a fence and signs posted on the fence. A minimum buffer zone of 6.1 m (20 ft) is maintained from the nearest adjacent property. There is no runoff generated on-site as all fields are bermed.

FACILITY OPERATIONS

The preapplication treatment portion of the system is well operated, and effluent quality in terms of BOD_5 and suspended solids averages 4 and 1 mg/L, respectively. As provisions exist for surface discharge, on a yearly average, approximately 70% of the wastewater is land applied, while approximately 30% of the water is discharged to Hords Creek. Whenever the surface discharge is used, wastewater chlorination facilities are utilized. When irrigation is practiced, the wastewater is discharged unchlorinated to the fields.

Depending on antecedent weather conditions, wastewater is generally applied 12 months of the year, 24 hours per day. The field to be irrigated is chosen by visual estimates, and fields are rotated with two or three fields irrigated at the same time. In terms of operation of the irrigation system, all wastewater application is performed by the City of Coleman staff. Fertilization and cattle management are the responsibility of the private farmer who leases the area. The lease stipulates that the farmer must pay $3,000 per year for use of the irrigation area. Currently, approximately 100 head of cattle are grazed on the fields nine months of the year. For the three winter months, the Bermuda grass is somewhat dormant, and the cattle are moved elsewhere and fed. The operator reported no operational headaches associated with running the irrigation system. Approximately one hour per day of the superintendent's time is spent with the irrigation fields.

FACILITY MAINTENANCE

The maintenance of the preapplication treatment system appeared good, and there were no problems in terms of maintenance reported by the operator except for bearings on the brush aerators. Owing to the inherent simplicity of the wastewater distribution system, maintenance problems are at a minimum. Occasionally (approximately every three to four years) the earthen- and grass-lined ditches must be rehabilitated, but that is basically the only maintenance performed in the area.

OPERATION AND MAINTENANCE COSTS

The City of Coleman Wastewater Treatment Plant spent $34,900 on wastewater treatment during fiscal year 1978-1979. Of this total, only $1,050 or 3% was spent on land treatment with this reflecting time spent by the operator. The cost is totally defrayed by the $3,000 per year received for leasing the land. As effluent must be pumped to the surface discharge, no cost is associated with pumping the wastewater to the land treatment system.

DESIGN DEFICIENCIES

During the site visit, the operator indicated that there were no design deficiencies with the land treatment system. However, since the wastewater is pumped to the preapplication treatment facilities and then pumped to either the surface discharge or the land treatment system, this is a design deficiency. The hydraulics of the preapplication treatment system should have been designed so that wastewater could have flowed by gravity to the discharge.

CITY OF SANTA ANNA WASTEWATER TREATMENT PLANT (# 026)

SANTA ANNA, TEXAS

SLOW-RATE SYSTEM

GENERAL

The City of Santa Anna, Texas is located in central Texas, approximately 90 km (55 mi) southeast of Abilene (Figure A-76). The City of Santa Anna owns and operates the wastewater treatment plant. The land treatment system is owned by a private farmer, but is partially operated by the City. The facility was visited on June 11, 1980.

The Santa Anna area is categorized by a mild climate. The average annual temperature is 18.6°C (65.4°F). The average yearly rainfall is 0.7 m (26.82 in), whereas the mean annual estimated Class A pan evaporation is 2.4 m (95 in).

The Santa Anna wastewater preapplication treatment system consists of preliminary treatment, followed by primary treatment, and biological treatment in oxidation ponds (Figure A-77). Effluent from the oxidation ponds is stored in holding basins prior to application to a field on which alfalfa and Johnson grass is grown. The field is utilized as a pasture for cattle. The land treatment system is operated in the slow-rate mode.

The City of Santa Anna Wastewater Treatment Plant was designed to handle 568 m^3/day (150,000 gpd). The current flow to the treatment facility is 50% of the design flow. The plant receives 100% domestic sewage.

The City of Santa Anna Wastewater Treatment Plant and the adjacent land treatment system have been in operation for 14 years. The facility is located in an agricultural area. Plans for the future call for additional acreage to be irrigated utilizing the recycled water.

PHYSICAL FACILITIES

The influent wastewater to the Santa Anna Wastewater Treatment Plant flows through one of two hand-cleaned bar screens,

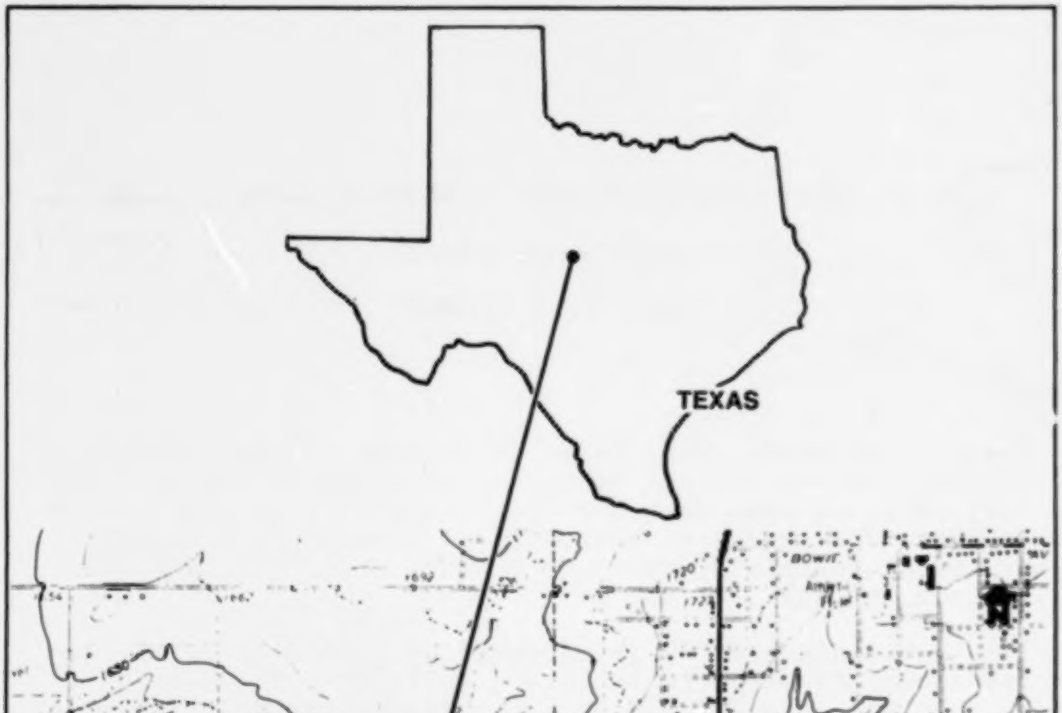
TEXAS
Creek
Gravel Pit
Oil Well
Gravel Pits
Creek
SANTA ANNA (BREN
OIL FIELD
Gravel Pits
Preapplication and Land Treatment Area
Horse
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-76. Location map of City of Santa Anna wastewater treatment plant (# 026), Santa Anna, Texas.

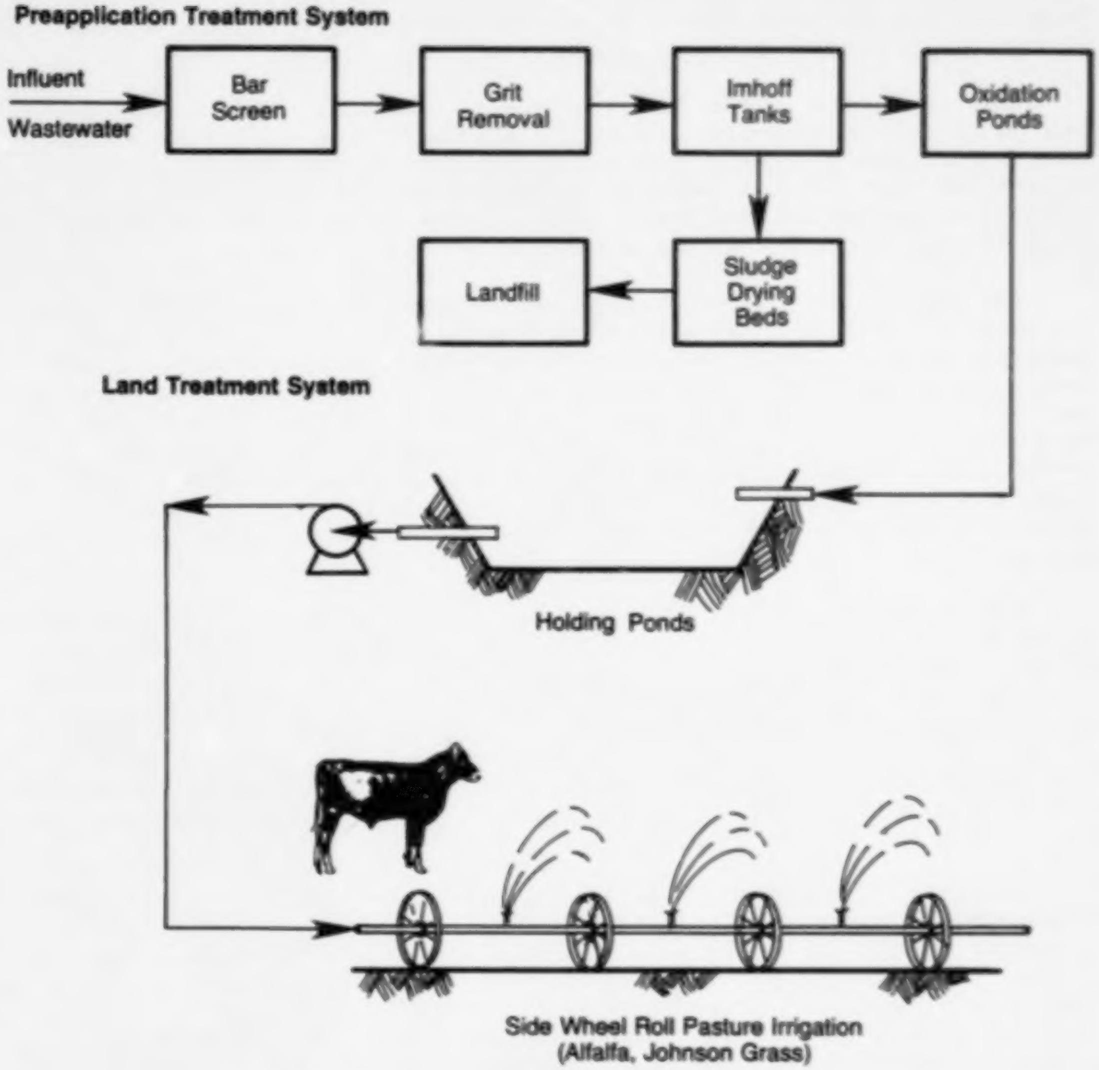
Preapplication Treatment System
Influent
Wastewater
Bar Screen
Grit Removal
Imhoff Tanks
Oxidation Ponds
Sludge Drying Beds
Landfill
Land Treatment System
Holding Ponds
Side Wheel Roll Pasture Irrigation
(Alfalfa, Johnson Grass)

Figure A-77. Process flow diagram of City of Santa Anna wastewater treatment plant (# 026), Santa Anna, Texas.

through a grit chamber, and then through a Parshall flume with a recording device. The wastewater then flows by gravity to an Imhoff tank. From the Imhoff tank, the water flows to one of two oxidation ponds operated in series. The digested sludge from the Imhoff tank flows to sludge drying beds. The dried sludge is disposed of in a local landfill.

The oxidation ponds have an area of 2.0 ha (5.0 acres) each. The oxidation ponds are 2.1 m (7 ft) deep, and each has a capacity of 43,154 m^3 (11.4 mil gal). Based on the design flow, a detention time of 152 days is provided by the two ponds. The oxidation ponds are unlined. Wastewater flows from the first pond to the second pond by gravity.

The oxidation pond effluent overflows the second pond, passes through a diversion structure, and flows to the first of two holding ponds. The exact size of the two holding ponds is not known, however, the total surface area is believed to be approximately 2.0 ha (5 acres), and the total capacity is believed to be on the order of 43,000 m^3 (11.4 mil gal). The holding ponds are unlined. The primary holding pond resembles a surface depression, and the water has been inundating some neighboring trees. The ponds have a 76-day detention time at the design flow.

The slow-rate land treatment system consists of irrigation of 10.9 ha (27 acres) of land owned by a local farmer (Figure A-78). The farmer also owns an additional 5.3 ha (13 acres) of pasture which is not irrigated. Currently, a mixture of alfalfa and Johnson grass is grown on the site, which is used as pasture for cattle. Wastewater is distributed on the fields utilizing one portable effluent pump located at the primary holding pond. The pump has a 5.6-kw (7.5 hp) motor, however, its rated capacity is unknown.

The pump discharges into an underground distribution system which goes to the nearby spray fields. In the spray fields it connects to one of six riser pipes. The riser pipes are connected to a side-wheel roll sprinkler. The sprinkler is 183 m (600 ft) long, with the sprinklers located 3.0 m (10 ft) apart. Typical impact sprinkler heads are utilized. The entire spray field is bermed to contain any runoff from leaving the site.

The loading rates at the site (excluding pond evaporative losses) are as follows:

Hydraulic	0.95 m/yr 18.3 mm/wk

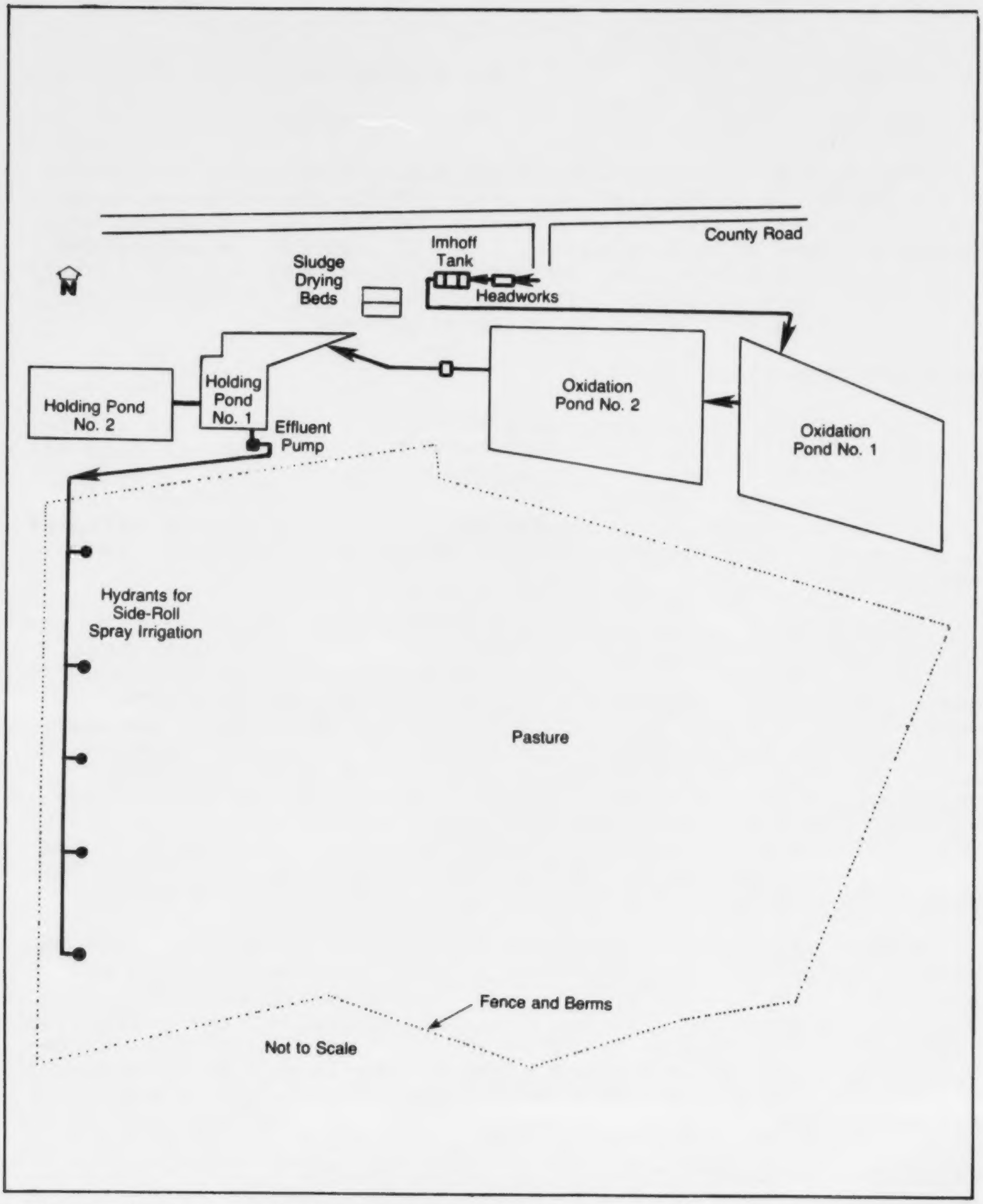
County Road
Imhoff Tank
Sludge Drying Beds
Headworks
N
Oxidation Pond No. 2
Oxidation Pond No. 1
Holding Pond No. 2
Holding Pond No. 1
Effluent Pump
Hydrants for Side-Roll Spray Irrigation
Pasture
Fence and Berms
Not to Scale

Figure A-78. Facility layout of City of Santa Anna wastewater treatment plant (# 026), Santa Anna, Texas.

Organic	266 kg BOD_5/ha/yr
Solids	578 kg SS/ha/yr

The soil in the vicinity of the Santa Anna spray irrigation field is mostly silt, clay and loam. There are no groundwater monitoring wells associated with the facilities. A buffer zone (minimum size) of approximately 305 m (1,000 ft) is maintained with neighboring property, as there is some nonirrigated pasture land which surrounds the irrigated portions of the facility. Site access is controlled by means of fences.

FACILITY OPERATIONS

The preapplication treatment facility is operated in a continuous mode, that is, the level in the oxidation ponds does not change, and only storage afforded by the two holding ponds is utilized. Based on one grab sample, the effluent quality from the oxidation ponds would be typical of an intermediate effluent with the BOD_5 and suspended solids being 28 and 61 mg/L, respectively.

The equipment associated with the land treatment system, although owned by the farmer, is operated by City of Santa Anna personnel. Based on factors such as antecedent rainfall and other climatic conditions, irrigation is carried out. The strategy for irrigation is to irrigate for eight hours per day, five days per week. This is accomplished by manually moving the sprinkler system from one riser to the next every two days. Therefore, every area is irrigated for eight hours per day for two days prior to the sprinklers being moved. As there are six separate irrigation risers the entire field is irrigated approximately every two weeks. The wastewater pump is on a timer for shut-off purposes, and must only be turned on every morning.

Approximately one hour daily is involved in checking out the system, moving the sprinkler every other day, and turning the system on. There have been no reported problems with sprinkler plugging or anything else out of the ordinary for the irrigation system. As the pasture is irrigated, twice as many cows can be raised in the area than would typically be raised on neighboring nonirrigated land. The cattle are removed from the pasture for the three winter months.

FACILITY MAINTENANCE

The preapplication facility has been adequately maintained as has the land treatment system. There were no reported major maintenance problems associated with the facility, and things appear to be running smoothly.

OPERATION AND MAINTENANCE COSTS

The City of Santa Anna plans to spend approximately $5,650 on wastewater treatment during fiscal year 1980-1981. Of this amount, approximately 46% or $2,590 is associated with land treatment. This is entirely for personnel, since electricity, maintenance, and repairs, etc. are paid for by the farmer.

DESIGN DEFICIENCIES

No design deficiencies were noted during the plant tour. However, city personnel felt that insufficient land existed for irrigation purposes. Based on the calculated application rate, this does not necessarily appear to be a problem. The problem may be, however, associated with the fact that sufficient storage does not exist. This problem could be corrected operationally by varying the depth of wastewater in the oxidation ponds.

CITY OF WINTERS WASTEWATER TREATMENT PLANT (# 027)

WINTERS, TEXAS

SLOW-RATE SYSTEM

GENERAL

The City of Winters, Texas is located in central Texas, midway between Abilene and San Angelo (Figure A-79). The wastewater treatment plant is owned and operated by the City of Winters, which also owns the property utilized for land treatment of wastewater. The land is rented out to a local farmer who operates the farm. The facility was visited on June 12, 1980.

The climate of Winters, Texas can be categorized as mild, semiarid. The yearly average temperature is 18.2°C (67.4°F). The average annual precipitation is 0.63 m (21.85 in). The mean annual Class A pan evaporation is 2.5 m (98 in).

The preapplication treatment in Winters, Texas consists of an Imhoff tank. Effluent from the Imhoff tank is pumped to three holding ponds for storage and subsequent use (Figure A-80). The water flows by gravity from the holding ponds into a border strip irrigation system. A total of 10.5 ha (26 acres) are irrigated in the slow-rate system.

The Winters wastewater treatment facilities were designed to handle 0.022 m^3/s (0.5 mgd). Currently, the plant is receiving 60% of this flow, or 0.013 m^3/s (0.3 mgd). Of the flow received at the facility, 100% is of domestic origin. The preapplication treatment and land treatment systems have been in use at Winters for 55 years.

Based on conversations with City of Winters personnel, it was learned that they have plans to replace the existing Imhoff tank with a larger, more modern facility; the type is undecided as yet. Land use adjacent to the land application site is mainly agricultural.

PHYSICAL FACILITIES

The wastewater generated in the City of Winters, Texas flows to the head end of the Imhoff tank where it receives the equivalent of primary treatment. Sludge generated is anaerobically

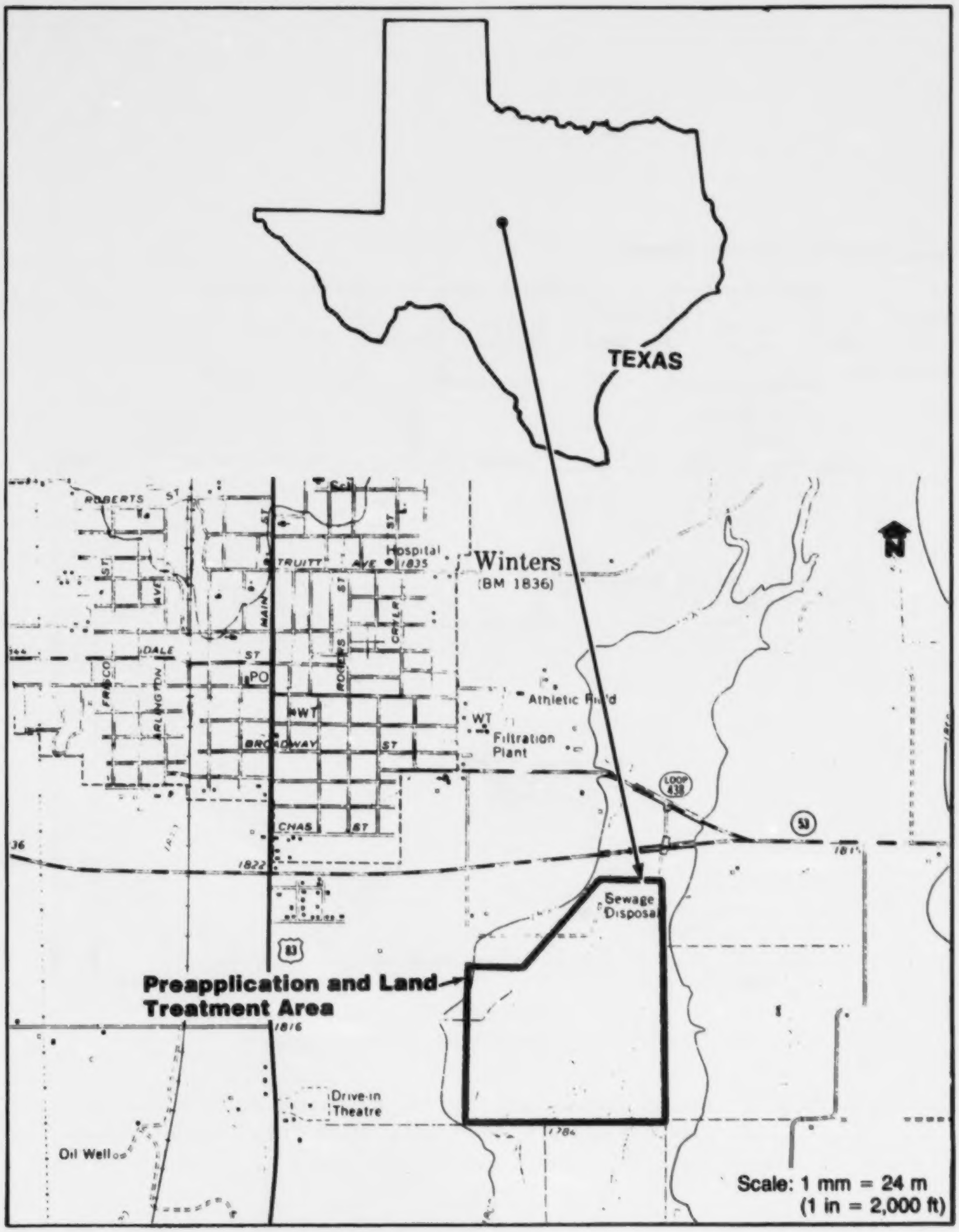
TEXAS
ROBERTS ST
TRUITT AVE
Hospital
1835
Winters
(BM 1836)
DALE ST
PO
NWT
BROADWAY ST
CHAS ST
MAIN ST
Athletic Field
WT
Filtration Plant
LOOP 438
53
1822
83
Sewage Disposal
Preapplication and Land Treatment Area
1816
Drive-in Theatre
Oil Well
1784
N
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-79. Location map of City of Winters wastewater treatment plant (# 027), Winters, Texas.

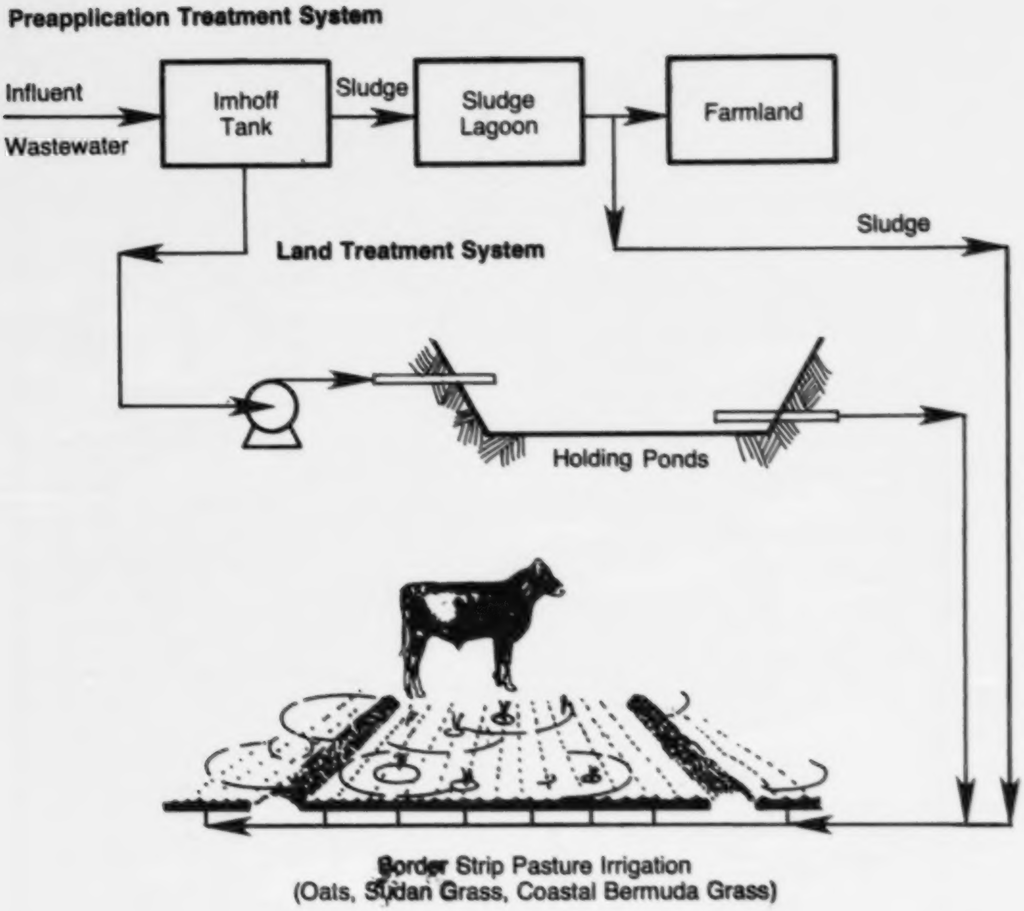
Preapplication Treatment System
Influent
Wastewater
Imhoff Tank
Sludge
Sludge Lagoon
Farmland
Sludge
Land Treatment System
Holding Ponds
Border Strip Pasture Irrigation
(Oats, Sudan Grass, Coastal Bermuda Grass)

Figure A-80. Process flow diagram of City of Winters wastewater treatment plant (# 027), Winters, Texas.

digested in the lower compartment of the Imhoff tank, and is withdrawn and pumped to an adjacent unlined sludge lagoon. The sludge is occasionally withdrawn from this lagoon and sprayed on agricultural property.

The effluent from the Imhoff tank flows into a level-controlled wet well, then it is pumped out utilizing one of two centrifugal nonclog pumps. The pumps are rated at 11.2 kw (15 hp). Each pump is capable of pumping 0.044 m^3/s (700 gpm). The force main from the pump is approximately 91 m (300 ft) long, and passes under a creek and to a series of three holding ponds.

Although not designed as oxidation ponds, owing to the quality of the primary treated effluent, the ponds act as oxidation ponds. The three ponds were estimated to be 0.81, 0.81, and 1.62 ha (2, 2, 4 acres) each. The ponds are approximately 0.91 m (3 ft) deep. The estimated capacity of the three ponds is 7,571 m^3 for the first two ponds, and 15,142 m^3 for the third pond, for a total capacity of 30,284 m^3 (8 mil gal). Based on the design flow rate, a storage capacity of 16 days is provided by the three ponds. The ponds are unlined.

All of the property at the land application site is owned by the City of Winters. However, every five years, sealed bids are taken for use of the 49.4-ha (122 acre) site. Currently, the farmer is paying $8.09/ha/yr ($20/acre/yr) for use of the facilities. Of the entire area, however, only 10.5 ha (26 acres) can be flooded utilizing border strip irrigation (Figure A-81). An additional 6.1-ha (15 acre) field can be spray irrigated. The farmer must supply the pump and piping, however. The remainder of the site is partially wooded pasture land.

The area that is operated as a border strip irrigation system is flooded by means of opening a disc gate in the bank of one of the holding ponds. This either lets the wastewater directly out into one of the border strips, or into a drainage swale. If the water is discharged into a drainage swale, it eventually irrigates one of the fields by a clay pipe through a berm in a border strip irrigation field. The crop grown in the border strip area is coastal Bermuda grass. This grass is either harvested and baled for future animal feed use, or is used directly as pasture.

Aside from the coastal Bermuda grass, oats have also been planted in the field. At the time of the visit, the oats had been harvested, and the fields were being grazed by sheep. Cattle also graze the area. At the time of the visit the cattle

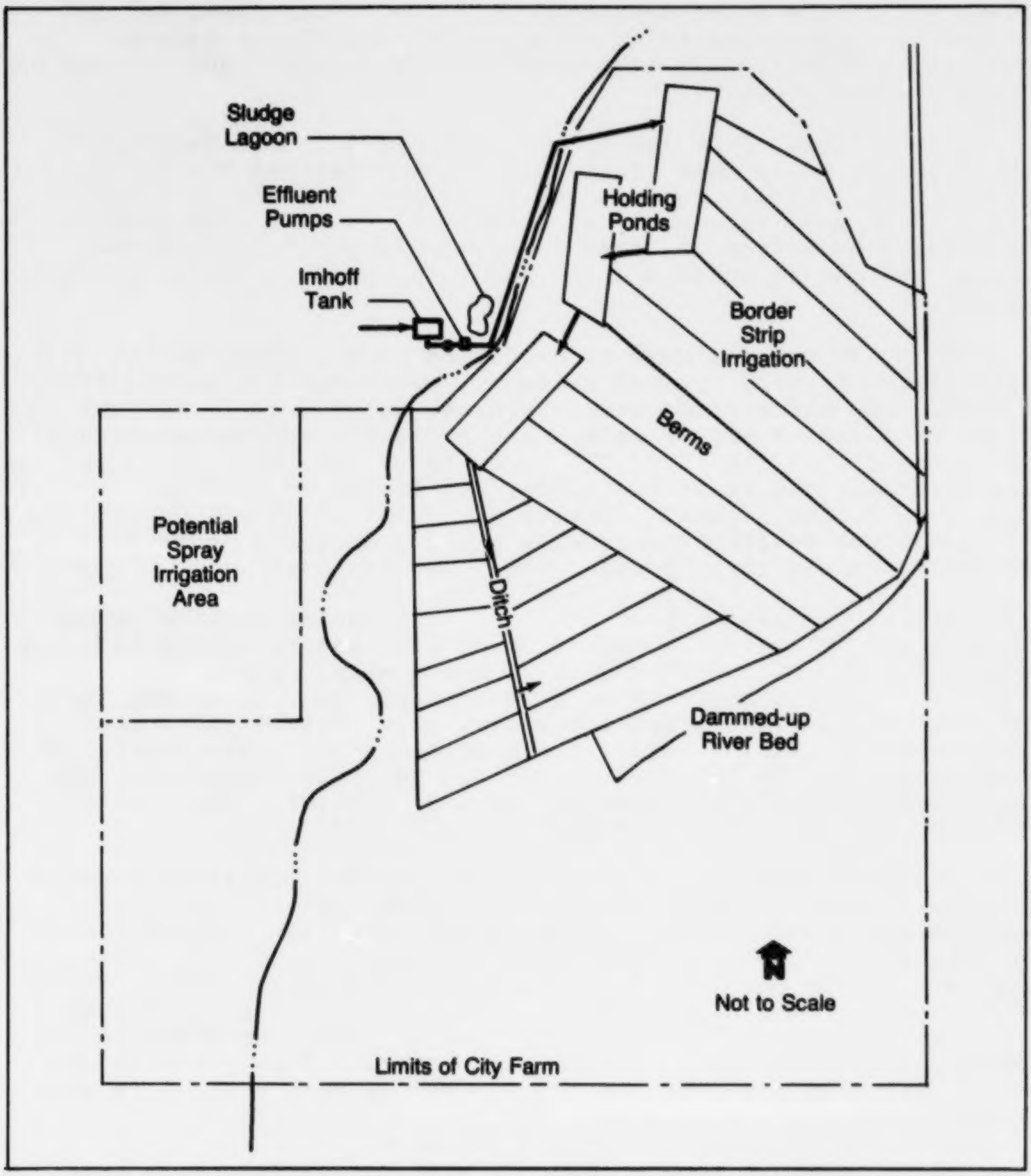
Sludge Lagoon
Effluent Pumps
Imhoff Tank
Holding Ponds
Border Strip Irrigation
Berms
Potential Spray Irrigation Area
Ditch
Dammed-up River Bed
N
Not to Scale
Limits of City Farm

Figure A-81. Facility layout of City of Winters wastewater treatment plant (# 027), Winters, Texas.

were in the nonirrigated pasture area. The 6.1-ha (15 acre) site that is also occasionally spray irrigated is irrigated utilizing portable aluminum pipe and a portable pump. The City supplies none of the required equipment.

The land application system also includes additional water storage capacity in a dammed-up creek bed. This containment area is used to store excess effluent when there is no available capacity in the three other ponds, and also collects any excess water which may be applied to the fields. There is no estimate as to the size or capacity of this creek bed. The soils which underlie the land application area contain sand, silt, loam, and clay.

There are no groundwater monitoring wells in the area of the treatment plant or the land application fields. A buffer zone exists between the land application site and the neighboring properties. At a minimum it is 30.5 m (100 ft) wide. As discussed previously, runoff from the flood irrigation system is collected in the dammed-up creek bed. The area is fenced to control public access, and contain the animals that graze onsite.

Based on the 1973 analytical data (not including evaporation losses), the following loading rates have been calculated:

Hydraulic	4.0 m/yr 76.2 mm/wk
Organic	1,775 kg BOD_5/ha/yr
Solids	2,365 kg SS/ha/yr

FACILITY OPERATIONS

The preapplication treatment facility at the time of the visit was deplorable. The effluent pumps were down recently, and the site had flooded, and had yet to be cleaned up. There were few data available to assess the quality of effluent from the facility. The only data available were from the 1973 Needs Survey, and these data indicated that the plant produces BOD_5 and suspended solids of 45 and 60 mg/L, respectively. It is not known, however, where the samples were collected.

The farmer who leases the land application site actually has his hands tied when it comes to facility operations. First, he is obligated to take all the wastewater, and second, the majority of the leased areas cannot be irrigated due to the inflexibility and design of the system and the equipment available.

The farmer attempts to do his best, given the circumstances. Therefore, he floods the fields during the winter and/or growing season in order to get rid of the water, yet maximize crop production and grazing in adjacent fields. A second operational strategy that the farmer employs is to irrigate just prior to a rainfall event. This has a two-fold advantage; first, the animals do not like to eat grass which has been irrigated because of the solids which are left behind. By irrigating just prior to a rainfall, the plants will be washed off and the animals will regraze the area sooner. Secondly, the farmer has had some problems with the build-up of dissolved solids in the soil. By applying the wastewater just prior to a rainfall event, the subsequent leaching of solids can be improved. Conversely, the worse time to apply the wastewater is prior to rainfall as it will do the least good, and potentially the most damage due to overwatering.

An additional problem associated with irrigating the field and keeping it wet is a health problem associated with sheep. Sheep typically excrete a parasite, and when this parasite is in wet soil it lives longer, and therefore, the potential for transmission of disease is greater. An additional problem the farmer must deal with is the site layout -- he cannot get from one irrigation area to another without traveling a considerable distance. He must drive through creeks and woods to get from one treated area to another, and this increases the difficulty of operation.

Crops grown on the site include coastal Bermuda grass and oats in the border strip irrigation area. In addition, a hybrid grazer grass (Sudan grass) is grown on the 6.1-ha (15 acre) site. This site is infrequently watered due to the cost of pumping the water, in terms of both electricity and manpower involved. Two types of grazing animals are raised on-site. The first of these is sheep. The sheep are grown for meat; their wool is of secondary importance. In addition, cows are also grazed on-site. The cows and sheep are typically kept in different pastures since the sheep eat the grass very low, the cows cannot graze the area. There is no attempt made to keep the animals off the area being irrigated, as they are not very fond of the wastewater, and when irrigation commences, the animals move away.

FACILITY MAINTENANCE

The preapplication treatment system which consists of an Imhoff tank and pumping station appears poorly maintained. This may be indicative of the fact that the City is looking toward replacement of the system, and does not care to invest in keeping up the facility. In terms of maintenance, there is minimal maintenance to be done at the land treatment site since the wastewater distribution system consists of earthen-lined channels and a few disc gate valves. There do not appear to be any maintenance problems which materially affect the operation of the land treatment system.

OPERATION AND MAINTENANCE COSTS

The City of Winters, Texas annually spends $4,905 on wastewater treatment. It is estimated that approximately $900 of this total, or 22%, is utilized for land treatment. This cost is associated with pumping the effluent water to the holding pond. The cost of operation and maintenance is, in part, defrayed by the approximately $2,440 received annually for rental of the land treatment site.

DESIGN DEFICIENCIES

The major design deficiency at the plant involves the plant layout. When the plant was constructed, a very poor job was done in plant layout, and facilities are located rather haphazardly around the site. For example, only 21% of the total area of the site can be irrigated by gravity, however, all wastewater is pumped to the holding basin. Pumping to a higher elevation water holding basin would have enabled larger areas to be irrigated. In addition, by locating the holding basins and fields in different positions, access from one area to another area could have been simplified, thereby saving the farmer a lot of time.

A second design deficiency is the fact that only 16 days of storage capacity was designed into the system. This causes effluent water to be applied when it is not required. This further complicates the stable operation of the facility. In summary, the design deficiencies have effectively made the plant less than 100% operable.

CITY OF SWEETWATER WASTEWATER TREATMENT PLANT (# 028)

SWEETWATER, TEXAS

SLOW-RATE SYSTEM

GENERAL

The City of Sweetwater, Texas is located in central Texas, approximately 48 km (30 mi) due west of Abilene, Texas (Figure A-82). The wastewater treatment facility is owned and operated by the City of Sweetwater, Texas. The land application system is owned and operated by a private farmer. The City of Sweetwater Wastewater Treatment Plant and adjacent farms were visited on June 13, 1980.

The climate in the Sweetwater area is mild. The average annual temperature is 17.4°C (63.3°F). The annual precipitation averages 0.56 m (22.19 in), whereas the mean annual Class A pan evaporation is estimated to be 2.5 m (100 in).

The City of Sweetwater Wastewater Treatment Plant consists of preliminary treatment and primary sedimentation followed by trickling filter biological treatment (Figure A-83). Based on analytical data, the plant is producing a secondary effluent. The land treatment system is an irrigation system operated in a slow-rate mode. A total of 115 ha (285 acres) of land is utilized for the irrigation system. All irrigation is accomplished by border strip flooding.

The Sweetwater facility was designed to handle 0.088 m^3/s (2 mgd). Current flows at the facility, however, average 0.044 m^3/s (1.0 mgd). Of this flow, approximately 10% is contributed by industrial sources, including a gypsum plant and a meat packing plant. Both the preapplication treatment and the land treatment facilities have been operating for 22 years. The land application facility is located in an agricultural area. There are no plans for future changes at either the preapplication treatment or land treatment sites.

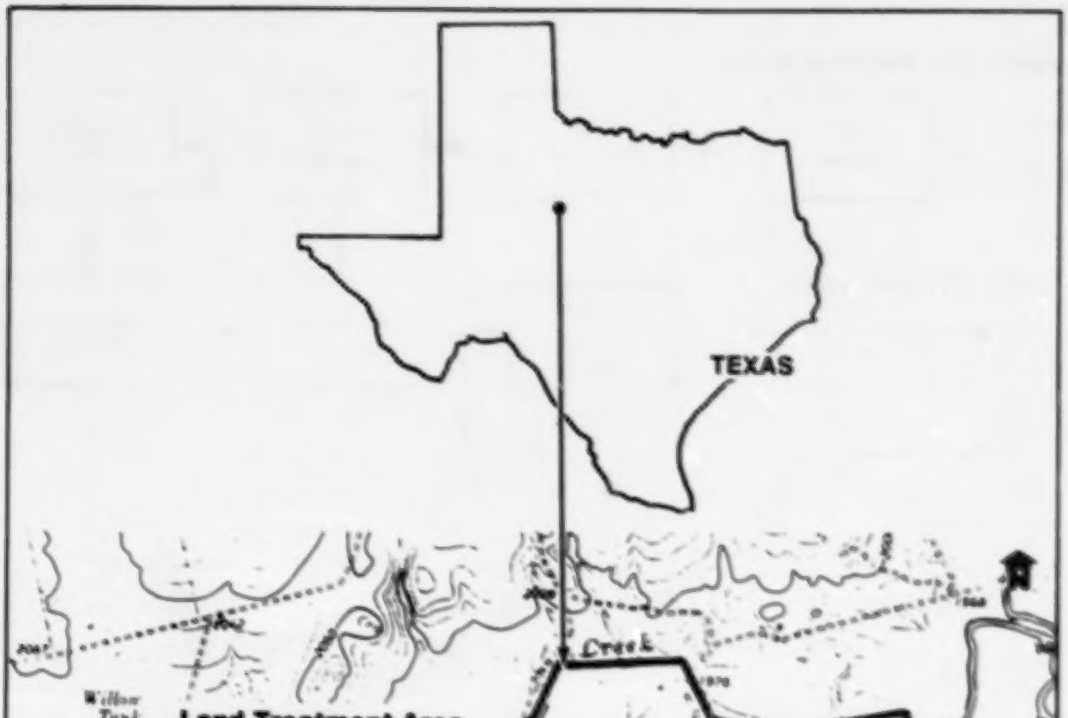
TEXAS
Creek
Willow Tank
Land Treatment Area
Sweetwater
ATCHISON
PACIFIC
AND
TEXAS
Gravel Pits
Old Wells
Well
Old Well
Sewage Disposal Ponds
Preapplication Treatment Facility
Gravel Pit
Scale: 1 mm = 24 m
(1 in = 2,000 ft)

Figure A-82. Location map of City of Sweetwater water pollution control plant (# 028), Sweetwater, Texas.

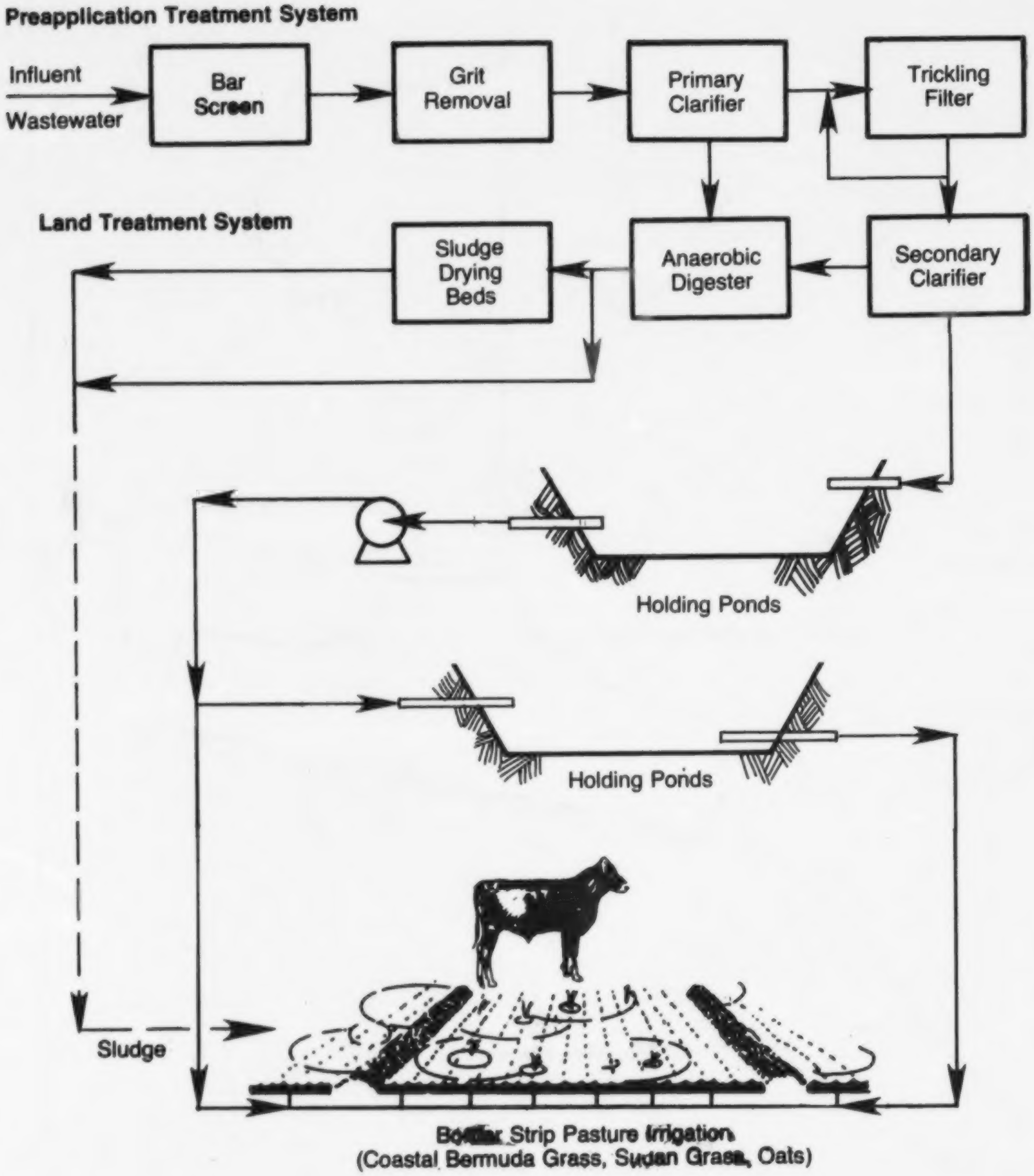
Preapplication Treatment System
Influent
Wastewater
Bar Screen
Grit Removal
Primary Clarifier
Trickling Filter
Land Treatment System
Sludge Drying Beds
Anaerobic Digester
Secondary Clarifier
Holding Ponds
Holding Ponds
Sludge
Border Strip Pasture Irrigation
(Coastal Bermuda Grass, Sudan Grass, Oats)

Figure A-83. Process flow diagram of City of Sweetwater water pollution control plant (# 028), Sweetwater, Texas.

PHYSICAL FACILITIES

All wastewater received at the Sweetwater, Texas facility is first pumped to the preliminary treatment facility by way of an on-site pumping station. The headworks to the facility consists of a Parshall flume followed by a hand-cleaned bar screen, followed by a circular grit chamber. All grit is removed utilizing a screw conveyor and disposed of in a landfill. Primary treatment is accomplished utilizing one circular primary clarifier.

Following primary clarification, the wastewater flows by gravity to a circular, rotating boom trickling filter. A rock media is used in the trickling filter. Effluent from the trickling filter flows to a circular secondary clarifier. Sludge from both the primary and secondary clarifiers is pumped to the two-stage high-rate anaerobic digester for subsequent stabilization. Sludge from the digester is then pumped to sand drying beds for dewatering. Provision also exists for pumping the anaerobically-digested sludge to the adjacent farmland for direct land application.

The trickling filter effluent is not chlorinated, but rather flows by gravity to the first of three holding ponds operated in series. The first and second ponds have capacities of 20,440 m^3 (5.4 mil gal). The third pond has a capacity of 34,070 m^3 (9 mil gal). The first two ponds have a depth of 1.2 m (4 ft) whereas the third pond has a depth of 1.8 m (6 ft). The first two ponds cover an area of 1.6 ha (4 acres), whereas the third pond covers an area of 1.9 ha (4.6 acres). Based on the design forward flow, a 10-day detention time is afforded by the three ponds. All three ponds are unlined. From the third storage pond, wastewater is pumped approximately 1.8 km (1.1 mi) to a holding pond located at the farm. The pump is a 5.6-kw (7.5 hp) centrifugal pump rated at 0.044 m^3/s (695 gpm).

All equipment downstream of the effluent pump is owned and operated by the farmer. A total of 115 ha (285 acres) is irrigated utilizing border strip irrigation (Figure A-84). Individual plots vary in size from approximately 0.3 ha (0.75 acres) to 0.61 ha (1.5 acres). Each plot is approximately 30.5 m (100 ft) wide, and graded to a 1% slope. All wastewater distribution is accomplished by gravity, and wastewater which is pumped from the preapplication treatment facilities is discharged either to an elevated earthen storage basin or directly to the distribution system. The storage basin covers approximately 0.4 ha (1 acre) and has a capacity of 4,160 m^3 (1.1 mil gal). Wastewater is distributed through a series of concrete pipe and gate valves to the approximately 200 plots located on-site. The flood irrigation is accomplished utilizing irrigation hydrants approximately

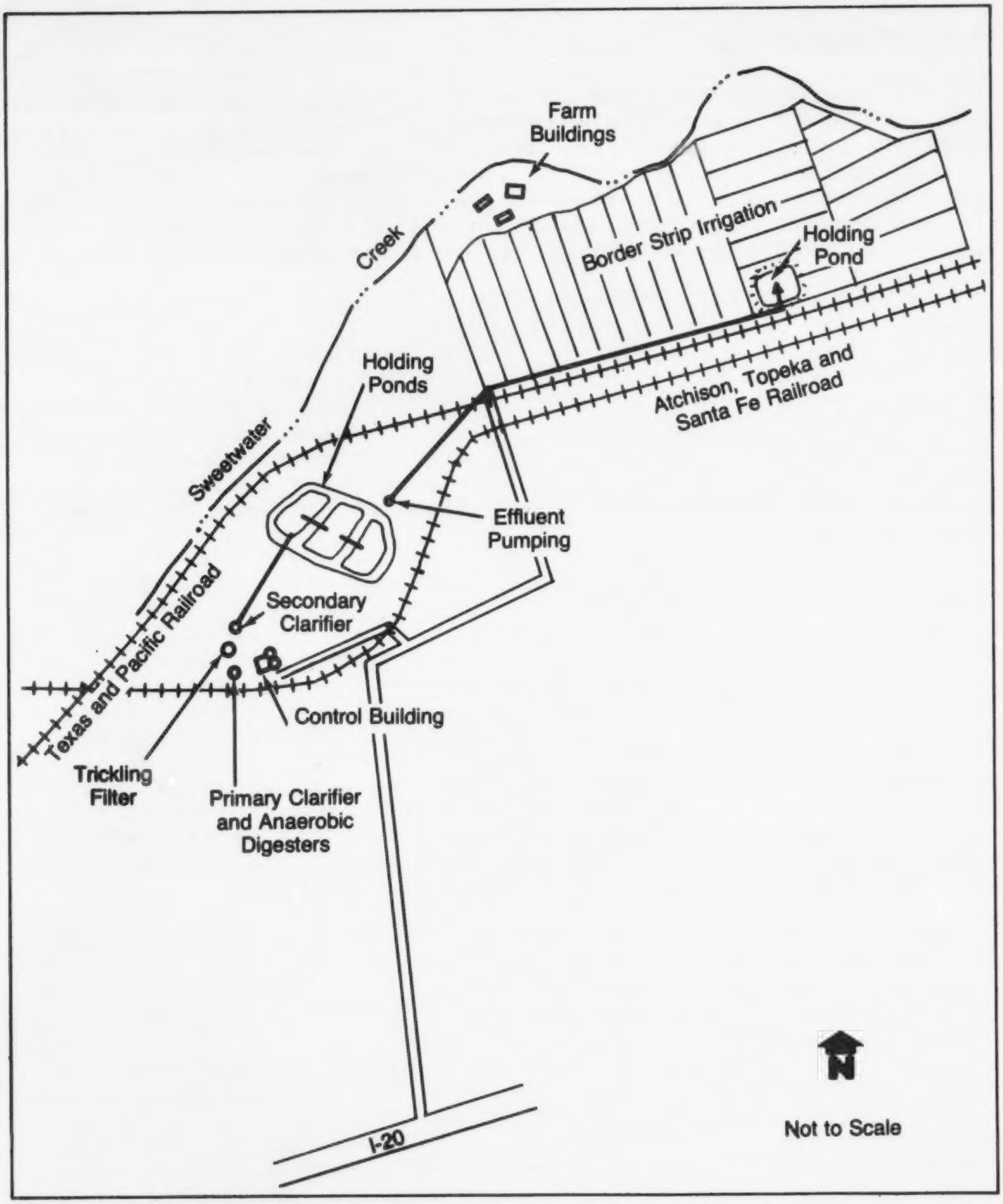
Farm
Buildings
Creek
Border Strip Irrigation
Holding
Pond
Holding
Ponds
Atchison, Topeka and
Santa Fe Railroad
Sweetwater
Effluent
Pumping
Texas and Pacific Railroad
Secondary
Clarifier
Control Building
Trickling
Filter
Primary Clarifier
and Anaerobic
Digesters
N
Not to Scale
I-20

Figure A-84. Facility layout of City of Sweetwater water pollution control plant (# 028), Sweetwater, Texas.

0.5 m (18 in) high which are typically located at the corner of four basins. When the plots are to be irrigated, a cover valve fits over the hydrant. The cover is equipped with a valve opening device and a pipe to irrigate one of the four adjacent fields.

The wastewater farm was designed after a facility in Lubbock, Texas, and was designed to maximize crop production. Therefore, there are three on-site holding basins. These basins are used to divert and store wastewater when the fields do not require irrigation. This allows the farmer the operational flexibility of not having to flood any fields. There is no estimate as to the capacity of the three basins. The basins are operated as evaporation/percolation basins, and there has never been a need to pump water from these basins back to the fields.

The soil which underlies the land treatment system is basically silt, loam, and sand. Four different crops are grown at the land application site, including Bermuda grass, Sudan grass, wild oats (Rescue grass), and winter wheat. Crops are typically rotated. The loading rates (excluding any water sent to the evaporation/percolation basins and any evaporation) at the land application site are as follows:

Hydraulic	1.2 m/yr 45.7 mm/wk
Organic	215 kg BOD_5/ha/yr
Solids	132 kg SS/ha/yr

No monitoring wells are located at the land treatment or treatment plant sites. A buffer zone of approximately 15 m (50 ft) is maintained on one side of the site. On the other three sides, the farmer owns additional pasture land, and a large buffer zone exists. There is no stormwater runoff from the site as all water would be contained within the bermed flood irrigation field. Site access is controlled by fences, which are also posted, since animals graze on the land.

Contractually, the farmer has rights to the water for a 99-year period which began in 1958. The farmer required long-term rights prior to investing the large sum of money for site work and equipment. Although he is required to utilize all of the water, the water must meet a minimum quality specification.

FACILITY OPERATIONS

The preapplication treatment system appeared relatively well run and produces a secondary effluent. The effluent quality for BOD_5 and suspended solids is 18 and 11 mg/L, respectively.

The land treatment system is run like any other well-managed farm, and the wastewater serves only as a source of water. Therefore, all irrigation is carried out as it would be on any other neighboring farm utilizing irrigation. During the summer months only 60.7 ha (150 acres) are irrigated. The crop grown on the irrigated fields is coastal Bermuda grass with a small amount of Johnson grass present. During the winter, the other 54.6 ha (135 acres) are irrigated, and the crop grown is Rescue grass (wild oats).

In terms of wastewater irrigation practices, the operating strategy is to apply 0.1-m (4 in) of water to approximately five plots at a time. Once the 0.1-m (4 in) is applied, the fields are rotated. Based on the number of fields irrigated, each field is irrigated approximately every three weeks. During irrigation, a tank truck holding anhydrous ammonia is parked at the irrigation riser pipe and the ammonia is applied in conjunction with the wastewater.

The coastal Bermuda grass normally grows approximately 0.91 m (12 in) every three weeks, and then is cut and baled. The coastal Bermuda grass is irrigated for six months during the summer. During this time the grazing animals are kept on non-irrigated pasture (including part of the flood irrigation site), pasture land adjacent to the irrigation site, and land adjacent to the holding ponds on the Sweetwater treatment plant site. During the winter months, however, the animals (basically cattle) are allowed to graze on the coastal Bermuda grass. During the winter, oats (Rescue grass) are grown on the irrigated plots. These same plots are not irrigated during the summer, and Sudan grass is grown for grazing purposes.

When the fields are irrigated, the cattle are not allowed on (and do not like) the irrigated fields. All planting, cutting, harvesting, maintenance, operations, irrigation, and fertilization is done by the farm staff which consists of one man full-time. The earthen berms that are between the flood strips grow not only Bermuda grass but a fair amount of weeds. The cuttings which contain weeds are cut separately and fed to goats which don't mind the weeds. The farmer believes that the farm will support one cow per 0.4 ha (acre).

FACILITY MAINTENANCE

The City of Sweetwater Wastewater Treatment Plant is adequately maintained, however, various process units do require some additional maintenance work, mainly in the form of painting.

The land treatment portion of the system appeared particularly well run. One maintenance problem which did manifest itself when the system originally began operation involved oil and grease contained in the wastewater. The oil and grease was associated with a slaughterhouse. The oil and grease would accumulate in the riser pipes which are used for ventilation purposes, clogging them, and causing problems with the wastewater distribution system. Since then the slaughterhouse has been forced to stop discharging the oil and grease, and the problem has been solved. Another problem noted was that the wastewater initially contained a higher than desired TDS content. Through cooperative efforts of the wastewater treatment plant personnel, the dissolved solids contained in the wastewater have decreased. This emphasizes the need for cooperative arrangements between wastewater treatment plant and farming personnel.

OPERATION AND MAINTENANCE COSTS

The City of Sweetwater spent approximately $74,750 during fiscal year 1979-1980 on maintaining their wastewater treatment facilities. Of this total, $4,490 (6%) was spent in conjunction with operating and maintaining their portions of the land treatment system. The breakdown is as follows:

Personnel	$2,010
Fuel and electricity	1,545
Maintenance and repairs	935
Total	$4,490

DESIGN DEFICIENCIES

Only one design deficiency was noted during the plant visit. This was the use of nonreinforced concrete pipe in the land application system. Originally, when there were problems with oil and grease accumulation in the vent pipes, surges would come through the pipes and cause the pipes to break, requiring their replacement. The farmer has since utilized reinforced concrete pipes for replacement and has apparently solved the problem of pipe breakage.

APPENDIX B

FIELD SURVEY QUESTIONNAIRE

Appendix B presents a copy of the questionnaire used during the site visit survey. The questionnaire included represents the final version, as the questionnaire was modified several times during the study to more adequately reflect the information desired.

Facility # _________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

1. General

1.1 Date: ______________________

1.2 Name of facility: ______________________

____

1.3 Address: ______________________

____

1.4 Telephone number: ______________________

1.5 Key personnel & titles: ______________________

____

____

____

1.6 Type land application system: ______________________

1.7 Degree of preapplication treatment: ______________________

1.8 Design flow rate (mgd): ______________________

1.9 Population served: Current ____________ Design ____________

1.10 Major industries served: ______________________

1.11 Years in operation: Preapplication treatment _____ Land application _____

1.12 Weather station information:

a. Station name and location: ______________________
b. Average annual temperature (°F): ______________________
c. Average annual precipitation (inches): ______________________
d. Mean annual Class A pan evaporation, estimated (inches): ____________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

1.13 Land use adjacent to the land application site

Residential ____________________
Commercial ____________________
Industrial ____________________
Agricultural ____________________
Other ____________________

1.14 Any definite plans for the future? Yes ________ No ________

If yes, explain

Expand ____________________
Upgrade ____________________
Abandon ____________________

1.15 Budget information Period ________ to ________

	Total Expenditure	Estimated Preapplication Expenditure	Estimated Land Application Expenditure
Personnel			
Materials and supplies			
Fuel and electric			
Chemicals			
Insurance (fire, etc.)			
Engineering service			
Communication			
Maintenance and repairs			
Equipment purchase			
Total			

1.16 Percent of total budget spent on land application ____________________%

Facility # __________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

1.17 Is there a special "Water Rights" agreement? Yes __________ No ___________

1.18 If yes, explain: ____

____

1.19 Do the users (farmers, etc.) pay for water received from this facility?

_______________ $/acre-foot.

1.20 Is there emergency power available? Yes __________ No __________

1.21 Are the emergency procedures in writing? Yes __________ No __________

1.22 Instrumentation system: Preapplication treatment: Yes _______ No ________

Land application: Yes _______ No ________

1.23 Electrical consumption: Preapplication treatment: __________ KWH per month.

Land application: __________ KWH per month.

1.24 Effluent from preapplication treatment to: Land application _____________%

Receiving stream _____________%

1.25 Drinking water source in the vicinity of the plant

Private well ________________ Public water system ________________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

1.26 Lab data

Record period from _____ to _____

	Influent	Preapplication Treatment Effluent	Type Sample G=Grab 8c=8hr Comp 24c=24 hr Comp	Sample Freq.	
Total Flow (mgd)					
Ind. Flow (mgd)					
Domestic (mgd)					
BOD_5 (mg/L)					
SS (mg/L)					
Fecal Coli. (#/100 ml)					
Total Coli. (#/100 ml)					
Other					

1.27 Type of State or Federal permit:

Operating permit only ________
Preapplication treatment quality ________
Surface water discharge quality ________
Ground water quality ________

2. Staffing

2.1 State certification: Order of classification:

Highest____Lowest

Facility # _________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

2.2 Employee Information

	Number	Annual Salary Range	Certification		Years Experience
			Req'd	Actual	
Superintendent					
Chief operator					
Shift operators					
Laborers					
Maint. personnel					
Lab technicians					
Summer help					

2.3 How many days are lost each year due to injury?

Preapplication treatment _________ Land application _________

2.4 Do operators attend continuing education courses? Yes _____ No _____

2.5 Do you formally evaluate operator performance? Yes _____ No _____

2.6 Do operators belong to a union? Yes _________ No _________

2.7 Which union? AFSCME _________ Other _________

2.8 Do the operators visit other plants utilizing land application as part of their training program?

Yes _________ No _________

Where ____

____

Facility # __________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

2.9 How many of the operators have previous land application or farming experience? ______________________________

2.10 Shift schedule

Man days including superintendent

	Monday through Friday			Weekend		
	Preappl.	Land appl.	Total	Preappl.	Land appl.	Total
Day						
Evening						
Midnight						

2.11 Overtime: Average hours of overtime worked per week per man? __________

2.12 Payment for overtime: 1-1/2 x _____ 2 x _____ 3 x _____ Other __________

2.13 Are the duties of the shift operators in writing? Yes ______ No ________

3. Preventative Maintenance

3.1 Is there any program for preventative maintenance? Yes ________ No ________

3.2 Does each piece of equipment have its own preventative maintenance card?

Yes __________ No __________

3.3 Is there a spare parts inventory? Yes __________ No __________

3.4 Is there a formal lubrication schedule? Yes __________ No __________

3.5 Is there a vendor manual file? Yes __________ No __________

3.6 Is there a valve exercise program? Yes __________ No __________

3.7 Is there a full time maintenance man or crew? Yes __________ No __________

3.8 Is there a tool room? Yes __________ No __________

3.9 Is there an O & M Manual on hand? Yes __________ No __________

If yes, does the manual specifically address land application?

Yes __________ No __________

Facility # __________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

3.10 Aside from instrumentation, is any maintenance done by a private contractor on a routine basis? Yes __________ No __________

4. Methods of Preapplication Treatment

4.1 Preliminary treatment:
a. Mechanically cleaned Bar screen __________
b. Bar screen __________
c. Comminutor __________
d. Barminutor __________
e. Grit removal __________
f. Other __________

Primary treatment:
g. Primary clarification___
h. Imhoff tank __________
i. Other __________

Secondary treatment:
j. Activated sludge _______
k. Trickling filter _______
l. Activated bio-filter____
m. Oxidation ditch ________
n. Aerated pond __________
o. Oxidation pond ________
p. Second. clarification___
q. Other __________

Disinfection:
r. Chlorination __________
s. Other __________

Tertiary treatment:
t. Filtration __________
u. Carbon adsorption ______
v. Dechlorination ________
w. Other __________

4.2 Method of sludge treatment:

a. Thermal __________
b. Gravity thickening __________
c. Flotation thickening __________
d. Anaerobic digestion __________
e. Aerobic digestion __________
f. Centrifugation __________
g. Vacuum filtration __________
h. Pressure filtration __________
i. Sludge drying beds __________
j. Sludge lagoons __________
k. Other __________

4.3 Methods of sludge disposal:

a. Landfilling __________
b. Land application __________
c. Incineration __________
d. Other __________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

4.4 Process Flow Diagram

Facility # _________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

5. Location Sketch

Facility # __________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

6. Land Application

6.1 Type of land application system: Slow Rate ______ Rapid Infiltration ______

Overland Flow ______

6.2 Wastewater distribution system:

a. Type: Gravity __________ Pressure __________

b. Description (size, spacing, coverage, pressure, etc.):

____

____

____

6.3 Monitoring wells

a. Number __________

b. Location (see sketch)

c. Depth __________ ft.

d. Sampling frequency __________

e. Parameters:

BOD_5 mg/L _____	NH_3 mg/L _____	mg/L _____
COD mg/L _____	NO_2 mg/L _____	mg/L _____
TDS mg/L _____	NO_3 mg/L _____	mg/L _____
TKN mg/L _____	PO_4 mg/L _____	mg/L _____

f. Ground water depth_____ ft.

Facility # _________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

6.4 Water Containment Basins

a. Number ____________________
b. Type ______________________
c. Capacity ____________ m.g.
d. Depth ______________ ft.
e. Surface Area ________ acres
f. Liner Material ____________

g. Problems ______________________
____
____

6.5 Buffer zone

a. Is there one? Yes _________ No _________ If yes, give:

b. Size: ____

c. How is it maintained? ______________________________

6.6 Is land application effluent recovered? Yes _________ No _________

6.7 What method is used for recovery?

Underdrains ________________
Tail water returns __________
Recovery wells _____________

6.8 Who manages the land application system?

Wastewater agency __________
Private farmer _____________
Other _____________________

6.9 Is surface runoff collected and/or diverted? Yes _________ No _________

Define: ____

____

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

6.10 Application Rates:

Hydraulic __________________in/yr

__________________in/wk (during application period)

Organic __________________lb BOD_5/acre/yr

Solids __________________lb SS/acre/yr

Nutrient __________________

____

____

Other __________________

____

____

6.11 What months of the year is land application system used? (Circle) JFMAMJJASOND

6.12 What are the criteria to determine when to shut down for or during the winter?

____

6.13 What are the criteria to determine when to start up in the spring?

____

6.14 Who harvests the crop? ____

6.15 What is the crop used for? ____

6.16 For overland flow systems, what is the dry up time prior to crop harvest?

____

6.17 Is public access permitted to the land application site? Yes ____ No ______

6.18 How is public access controlled? ______________________________________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

6.19 Land area used: ________

6.20 Value of land per acre: ________

6.21 Type of soil: Sand ________

Clay ________

Loam ________

Silt ________

Other ________

6.22 Slope of terrain: Flat (0-3%) ________

Moderate (3-8%) ________

Steep (Over 8%) ________

6.23 For the land application system is any process control testing conducted?

Yes ________ No ________

Explain ________

6.24 Is the land application system operated as originally designed?

Yes ________ No ________

If no, explain ________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH SUPERINTENDENT

6.25 List design deficiencies:

Page 1 of 2

Facility # _________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH FARMER/AGRONOMIST/SUPERINTENDENT

1. General

1.1 Are you maximizing crop production or wastewater disposal?

Crops _______________
Wastewater ___________
Both ________________

1.2 Are flotation tires or tracks used on equipment? Yes _______ No ________

1.3 Operating Strategy:

How is it decided when to apply and when not to apply wastewater?

Antecedent rainfall ________________ Other __________________________
Temperature _______________________ __________________________
Partially flooded fields ____________ __________________________

1.4 Has there been an increase or change in any of the following since initiation of land application?

Flies and insects ________________
Rodents ___________________________
Odors _____________________________
Plant diseases ____________________
Other _____________________________

1.5 Type of vegetation:

Grasses ___________________________
Vegetables ________________________
Grains ____________________________
Forest ____________________________
Other _____________________________

Facility # ________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/ CHECKLIST

INTERVIEW WITH FARMER/AGRONOMIST/SUPERINTENDENT

1.6 Are crops rotated? Yes ________ No ________

1.7 What is the lag time for grazing animals on pastures? ________________

1.8 Are farming practices at land application site (i.e. amount of irrigation, traction problems, fertilization, crop yield, etc.) different than at comparable neighboring sites growing same crops? Yes ______ No ________

If yes, explain ____

____

____

Page 1 of 1

Facility # __________

LAND APPLICATION
FIELD TRIP QUESTIONNAIRE/CHECKLIST

INTERVIEW WITH NEIGHBOR

1. General

1.1 Name ____

1.2 Address ____

____

		ODOR	MIST	NOISE	DUST	OTHER
1.3 Any problems:	No	____	____	____	____	____
	Sometimes	____	____	____	____	____
	Unbearable	____	____	____	____	____

1.4 How many years have you lived near the site? ______________________

1.5 Have there been any changes? Yes ______ No ______ Better ______ Worse _____

1.6 Have you ever been invited to tour the site? Yes __________ No _____________

1.7 Have you ever made a formal complaint? Yes __________ No __________ If yes,

To whom ____

What were the results ____

____

____

____

1.8 What is your source of drinking water?

Private Well __________ Public Water Supply __________

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